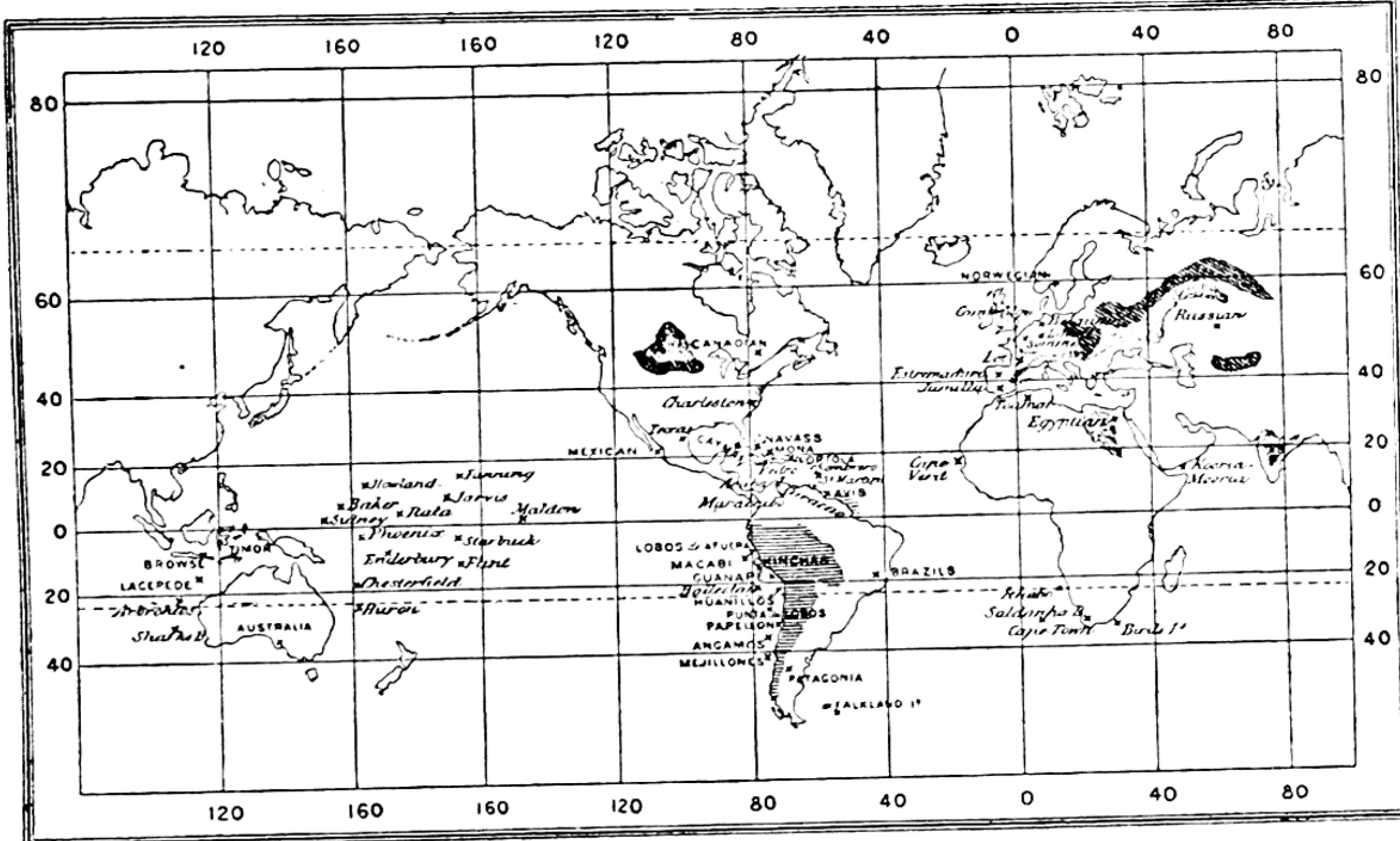
Bell's Agricultural Series.

MANURES AND THEIR USES.

A. B. GRIFFITHS.



THE WORLD.

(Showing the Manure deposits.)

× Guanos and phosphates.

Nitrate of soda.

Salt (in more or less quantities).

Potash salts (in more or less quantities).

MANURES AND THEIR USES:

A HANDBOOK

FOR

FARMERS AND STUDENTS.

377

BY

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TO

SIR RICHARD OWEN, K.C.B., M.D., D.C.L., LL.D., F.R.S.,

FOREIGN ASSOCIATE OF THE INSTITUTE OF FRANCE, KNIGHT OF THE PRUSSIAN ORDER "POUR LE MÉRITE," KNIGHT OF THE LEGION OF HONOUR, ETC.,

THIS WORK IS AFFECTIONATELY DEDICATED

AS A TOKEN OF GRATITUDE

FOR THE

KIND INTEREST HE HAS ALWAYS TAKEN

IN THE

AUTHOR'S SCIENTIFIC RESEARCHES AND WELFARE;

AND AS

A TRIBUTE OF ADMIRATION TO THE UNIQUE POSITION

WHICH

HE HOLDS AS THE GREATEST OF

PALÆONTOLOGISTS AND COMPARATIVE ANATOMISTS.

PREFACE

The art of manuring land is of paramount importance to the farmer and those engaged in agricultural pursuits; and believing as I do that it is still entitled to much more consideration and study, I have been induced to write the present volume, hoping that it may be useful to those who wish to become better acquainted with the scientific principles on which the art of manuring all cultivated lands is based.

I have been occupied for some years in the study of chemistry, biology, botany and collateral sciences; and having a firm conviction that scientific knowledge is a prime requisite in modern farming, I earenstly hope that my little volume will be the means of awakening new ideas in the rising generation of farmers.

Science, without doubt, is the farmer's best friend. What would become of the fertility of the broad acres of Great Britain without artificial manures? Barren lands would be the inevitable result of any

system of agriculture which ignored the use of manures.

The origin of the art of manuring is of great antiquity, and only survives in the traditions of the great centres of civilization of bygone ages. Its growth and development have been extremely slow. But it is gratifying to know that during the past few years farmers have turned, and are still turning, their attention more and more to the teachings of science; and it is to be hoped that the knowledge gained may be increased a hundred-fold.

The main object of the present work is to exhibit, in a concise form, various details concerning the use of manures and the art of applying them to the land.

In Chapter I. is a short sketch of the rise and development of British agriculture during the greater part of nineteen centuries; and Chapter II. is devoted to the principles of manuring.

I have also added a chapter giving the details of my own researches on the agricultural value of *iron sulphate* as a manure for various crops, which may prove useful for farmers and students.

The remaining eight chapters are devoted to details concerning the more important manures used in this and other countries.

My best thanks are given to Messrs. S. T. Griffiths, J. Coultas, H. Follows, F.C.S., W. Stevens, the

Directors of Lawes' Chemical Manure Co., Vipan and Headly, T. O. Kent, and the Directors of the Anglo-Continental Guano Co., for valuable information.

Having completed this "*labor absque labore*," I earnestly hope that it may prove useful in the hands of those interested in England's oldest industry.

A. B. GRIFFITHS.

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MANURES AND THEIR USES.

CHAPTER I.

THE RISE AND DEVELOPMENT OF BRITISH AGRICULTURE.

Believing that a sketch of the gradual rise and development of any branch of human industry forms an instructive as well as interesting prologue to a description of the *technique* of the industry in detail, this chapter is devoted to a brief review of the development of British agriculture from the time of the Romans to the present.

According to Hume, "Britain (under Roman rule) had assumed an aspect of great prosperity. Agriculture was carried to such a pitch that the island not only fed itself, but also exported large quantities of grain to the northern provinces of the empire."

There is little doubt that the ancient Britons learnt the "art" of cultivating the soil from their Roman conquerors.

Many Latin authors (including Columella, Pliny, Cicero, Cato, Virgil, and Varro) wrote upon the subject of agriculture, thereby diffusing a genuine love of farming and agricultural pursuits among the citizens of the mighty Roman empire. In those days, "the work of the farm

was the only kind of manual labour deemed worthy of a free citizen."

After Columella, the most prolific writer on ancient agriculture was Terentius Varro of Reaté (born 116 B.C.), who produced, at the age of eighty, a work on "Agriculture" (in three books), of the utmost importance.

Although the Romans loved the cultivation of the soil, they were, as everybody knows, far greater lovers of the "arts of war" than those of "peace." Hence, from the time of Hannibal's wars, agriculture lost ground in Italy.

The decline of agriculture in Italy proved the greatest boon to Britain, as well as to certain other dependencies of the Roman empire. The ancient Britons had been taught the agricultural art by their Roman masters, and in the fourth century we find the armies of Gaul and Germany chiefly depending for their subsistence upon the regular annual imports of wheat from Britain.

Zosinus, the historian, relates that in A.D. 359, the Emperor Julian despatched a fleet of over seven hundred ships to Britain for wheat. Besides wheat, Britain's farming industry supplied the Roman empire with horses, cattle, dogs, cheese, and MANURES (chalk, lime, and marl); and various Latin poets sang the praises of British horses and dogs.

During the Saxon period (449 to 1066), British agriculture suffered from the incursions of the Picts on the one hand and the invasion of the Saxons on the other. After the Saxons gained the upper hand, and the country was restored to tranquillity, the Britons taught them the art of farming.

According to Stow, "the English people (of this period) might have been said to be graziers rather than plough-

men, for almost three parts of the kingdom were set apart for cattle."

The Anglo-Saxon farmers did not generally understand the use of *manures*, although various Roman authors had previously written upon the importance of this branch of agriculture.[1] We learn from Smith's "Wealth of Nations" (Book I., chap. ii.) that the lands of this period which were manured did not amount to a fourth or fifth part of the whole farm. "The remainder was cultivated when that part of the farm which had been for some time arable was exhausted of its natural fertility."

Passing to the period which elapsed between 1066 and 1216, British agriculture once more suffered from "the devastations of the Conqueror at the commencement of the period, the wretchedness of the people during the nineteen turbulent years of Stephen's reign, and the lawlessness which distinguished the unprincipled reign of King John at its close."

On the authority of Peter of Blois, a crude system of manuring was in vogue during the period, which consisted in the extensive application of chalk and marls to various soils. In fact, we may call this period *The Age of Calcareous Manures.*

From 1216 to the end of the Plantagenets, the only additional manures recorded were the excreta of animals. In "Fleta" (a law book of the period), certain instructions are given for the collection of dung, and the mode of applying it to the land; "but the fertile properties of the soil were exhausted by taking off successive crops of the same kind."

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[1] See Dr. A. B. Griffiths' "Treatise on Manures," p. 2 (Whittaker & Co.).

During the next hundred years, or from 1399 to 1485, very little progress was made in the art of cultivating the soil. In this period "arable lands were to a great extent converted into pasture. The two great causes which contributed to bring about this change were: first, the scarcity of labourers, partly arising from their new position; and, secondly, the increasing value of wool, which rendered flocks more profitable than corn and grain."

During this and the preceding age, the culture of arable lands was very imperfect, no doubt largely due to the soils becoming *barren*, from continual cultivation of the same crops and the *scanty use of manures*. In Hallam's "State of Europe during the Middle Ages," we find "that unless an acre yielded more than six bushels of corn (!), the farmer would be a loser and the land yield no rent. And Sir John Cullum, from very minute accounts, has calculated that nine or ten bushels (!) of wheat per acre was a full average crop."

As every farmer knows, twenty-five to thirty bushels of wheat per acre are not uncommon yields in these days. There is little doubt that the most important consideration in a true system of husbandry is to pay the utmost attention to the cultivation of crops by the use of the all-important *plant-foods* which are called manures. Why are farmers able in this nineteenth century to obtain thirty bushels of wheat from an acre of land, while their ancestors in the thirteenth and fourteenth centuries only obtained at the outside ten bushels? Is not the population of Britain at the present time vastly greater than in the Middle Ages? And is not competition far keener? Notwithstanding that British agriculture has so many difficulties to contend with, the farmer of to-day is capable

of making the constantly cultivated lands yield thirty bushels of wheat per acre, the reason being that PRACTICE and SCIENCE have now taught him to use a variety of plant-foods which produce *healthy* and *luxuriant* crops.

Reverting once more to the history of our subject, we find that during the next hundred years or so (1485 to 1603), the development of agricultural methods becomes more assuring. "The restraining hand of Henry VII. checked much of that arbitrary and oppressive spirit which had so frequently been detrimental to industry, and with the increase of security there came an increase of industry, the progress of which was never afterwards relaxed; so that towards the close of this period the work of improvement was everywhere in operation." Harrison states that the soil had become more fruitful than in times past, and assigns as the cause that "our countrymen are grown to be more painful, skilful, and careful, through recompense of gain, than heretofore they have been." One acre produced now twenty bushels of wheat, or double the quantity of the preceding period. Norden, who wrote in the time of Queen Elizabeth, speaks of the additional attention paid by farmers and others to the manuring of lands.

During the reign of the Tudors, many authors wrote upon the subject of agriculture. Among these were Fitzherbert, Tusser, Platt, Goodge, Plattes, Hartlib (the friend of Milton), and others. Although books could have exercised but little influence on the minds of the rural classes, for the majority could not read, yet it appears that many of the ideas enunciated in Martin Tusser's work soon came into common use. Tusser wrote against the growth of the same crops year after year upon the same land. His well-known couplet,—

> "Still crop upon crop many farmers do take,
> And reape little profit for greedinesse sake,"—

had its value in turning the attention of agriculturists to a system of rotation which ultimately proved most beneficial for all lands. We also find from the writings of Sir H. Platt (1594) that there was a crude kind of "Agricultural Chemistry" in existence. Platt introduced into his volume on soils what he termed the "philosophical treatises" of MM. Bernard Palissy and Franciscus Valetius, upon the properties of the "*universal salt.*" But agricultural chemistry could not make any real progress in those days, because every experiment had first to undergo the test of accordance with "Holy Writ." And as they found "in Scripture *salt* figuratively spoken of as both a blessing and a curse, it occasioned much trouble to the philosophical essayists to reconcile the conflicting passages, and to harmonize their theory with both."

In the early days of the Tudors, the rotation of crops, usually followed, was of little value. After a crop of rye or wheat, oats or barley were sown in the spring, followed by a bare fallow. About the close of this dynasty, the cultivation of clovers was introduced into Britain from the Netherlands, which were additional crops in the rotation.

From 1603 to 1660 Britain was too frequently at war for any substantial progress to be made in the art of cultivation. During this period the Fen districts in the east of the country were extensively drained, thus adding considerably to the agricultural value of these lands.

In 1668 appeared Worlidge's "Systema Agricultura," a book which discussed drainage, irrigation, the cultivation of green crops, and the subject of drilling corn by machinery.

Lord Macaulay ("The History of England," vol. i., p. 148) states that, "in the year 1685, the value of the produce of the soil far exceeded the value of all the other fruits of human industry. Yet agriculture was in what would now be considered as a very rude and imperfect state."

Quoting from the author's "Treatise on Manures" (page 4): "During the seventeenth and eighteenth centuries, there is little to write upon concerning the '*art of manuring*,' farmers' attention being directed chiefly to the improvement of breeds of cattle and other farm animals." "The writers on agriculture in this period inform us that farmers were commonly slovenly in their husbandry, slow to practise new modes of culture, or to make use of new implements. Improvements were for the most part confined to the more intelligent of the country gentlemen, and to noblemen of large landed property." We find that many of these gentlemen farmers tried experiments on the fertility of different kinds of manures. Although bone-dust was used by Colonel St. Leger (on his farm near Doncaster) in 1765, this important fertilizer did not come into general use until at least sixty or seventy years later.

Passing from the last to the early part of the present century, we find, according to a certain writer, "that the progress of agriculture consisted chiefly in the furtherance of plans and improvements already commenced, but at a rate of advance truly astonishing. Attracted by the high prices of every description of agricultural produce, capital was freely expended in bringing land into cultivation, and in developing the fertility of that already under the plough. . . . Many of the practices of isolated districts which had become pre-eminent for their superior

husbandry, were brought into operation over a wider area. The wolds and clays were fertilized by chalk; marling rendered the barren sands fruitful; by the admixture of clay, the fens and peats became productive; and lime corrected the arid soil of the moorlands. Experiments were made on the *efficacy of manures and composts;* draining was more extensively practised; the improvement of live-stock was zealously pursued; root-crops and artificial grasses were more extensively cultivated, and new varieties of each introduced."

But, so far, agriculture had no fixed *principles*, and it was not until 1810 that Sir Humphry Davy gave to the world his work on "Agricultural Chemistry." This work was the first attempt to explain, upon a true *scientific* basis, the operations of manuring and cultivating soils. Thirty years after the appearance of Davy's book, the immortal Liebig published his famous volume, "Die organische Chemie in ihrer Anwendung auf Agricultur und Physiologie." This book is one of those few works which stand out from all others on the subjects of which they treat. It is undoubtedly the most important work on agriculture ever given to the world as the results of one man's researches and ideas.

From the year 1840 to the present time, all the various artificial manures known have come into general use, and it is the object of the present work to describe all the most important fertilizers used in British agriculture.

As a summary of our hasty review of the gradual rise and development of agriculture and the art of manuring, since the Romans taught our ancestors the rudiments of farming, we submit the following table chronologically arranged, which may be of use to students:—

TABLE OF MANURES USED IN BRITAIN

(During the greater part of nineteen centuries).

Periods.	Dates.	Manures.	General Remarks.
Roman .	B.C. 55 to A.D. 410	Dung, wood-ashes, lime, marl, and chalk.	Agriculture flourishing.
Anglo-Saxon and Danish	410 to 1066	Marls (chiefly).	No rotations of crops.
Norman and Plantagenet	1066 to 1399	Marls, chalk, and dung.	Bare fallows in use.
Houses of Lancaster and York .	1399 to 1485	Ditto.	Pastures largely in use. Wool, the most important item produced on the farm.
House of Tudor .	1485 to 1603	Dung, salt, lime, sand, coal-dust, fish-refuse, street-sweepings, malt-dust, vegetable-ashes, etc.	Great improvements in farming. A primitive system of rotation. A crude agricultural chemistry. Clover and potatoes introduced into husbandry.
House of Stuart, The Commonwealth and Restoration of the House of Stuart .	1603 to 1714	Farmyard manure (chiefly).	Improvements in breeds of cattle. Drainage of the Fen districts.
House of Brunswick .	1714 to 1840	Bone manures, farm-yard manures, salt, etc.	Great improvements in cattle breeding. Root crops (turnip and mangel-wurzel) introduced into husbandry.
	1840 to the present time	Bones, guanos, super-phosphates, nitrate of soda, ammonium sulphate, etc., etc.	Liebig formulates the laws of husbandry upon a scientific basis.

As everybody will agree with the author of Maccabees,[1]—"that it is a foolish thing to make a long prologue, and to be short in the story itself,"—we conclude this chapter in the words of Dr. A. W. Hoffman: "To keep up the fertility of his fields, the cultivator of the soil has to make himself acquainted with its general composition, as well as with the nature both of the particular substances which he is annually extracting from it, and of those with which he must supply the loss. For each of these purposes the aid of chemistry becomes indispensable to the farmer. . . . The nature of *manures* once clearly defined, almost every agricultural improvement at which practice had arrived by slow degrees, receives a satisfactory explanation, whilst a variety of improved applications necessarily suggested themselves. The *principles* of fallowing and of the rotation of crops, and the theory of soil-burning, are no longer mysteries; the action of lime, wood-ashes, and of bones is now perfectly intelligible. . . . Perhaps there is no more striking illustration of the value of the aid which agriculture has derived from her new ally, than the success which of late has attended the search for mineral manures. This search, directed by the philosophical interpretation of a few isolated facts, has been rewarded by the discovery of considerable quantities of phosphate of lime in various parts of England; thus realizing the prophetic anticipation of Liebig, that 'in the remains of an extinct animal world, England is to find the means of increasing her wealth in agricultural produce, as she has already found the great support of her manufacturing industry in fossil fuel, the preserved matter of primeval forests, the remains of a vegetal world.'"

[1] Maccabees ii., c. ii., v. 32.

CHAPTER II.

THE PRINCIPLES OF MANURING.

WHY do farmers add costly manures to their lands? What are the uses of manures? Cannot a full yield of wheat be obtained without nitrogenous manures, or of turnips without phosphates? No, it is impossible. It is an established fact, that if potash, lime, phosphates, sulphates, and nitrogenous substances are continually extracted from the soil by growing crops, unless these substances are restored in the form of manure, such soils must gradually lose their fertility, and poor sickly plants, liable to contract disease, will take the place of healthy ones capable of yielding full crops.

Therefore manures are of the utmost importance to the farmer. A farmer who manures his soils feeds his plants. Manures are plant foods. From the mineral substances of the soil, *plus* carbon and nitrogen, all farm seeds are capable of giving rise to mature plants, if they obtain a fair share of moisture, warmth, and sunshine.

Rotation of crops, or the method of alternately growing upon the same soil deep feeding plants and shallow feeders, or those crops requiring, say, chiefly phosphates, to be followed by those requiring nitrogenous manures, although most useful in any system of husbandry, does not keep the soils in a fertile condition.

Plants require for their development and growth an adequate supply of carbonic, nitric, sulphuric, and phosphoric acids; also potash, iron, lime, magnesia, silica, etc., all of which are indispensable, although some of

them are required in larger quantities than others. Thus, we speak of a wheat crop requiring liberal supplies of nitrogenous manures, turnips requiring phosphates, and potatoes potash. But other mineral ingredients are equally essential for the growth of these plants, although they are not absorbed in such large quantities.

The following two tables give the percentage compositions of the crops already mentioned:—

	Albuminoids.	Soluble Carbohydrates.	Woody Fibre.	Fat.	Ash.	Water.
Wheat (grain) .	11·30	68·1	3·0	1·5	1·7	14·4
[1] Wheat (straw) .	3·50	30·3	46·2	1·8	4·6	13·6
[1] Wheat (bran) . .	14·70	49·8	13·6	4·3	5·7	11·9
Turnips. . . .	1·10	5·3	1·0	0·2	0·7	91·7
[1] Potatoes . . .	2·24	21·36	1·0	0·21	1·21	73·97

By the term "ash" is meant the mineral matters derived from the soils, and may be obtained by burning the plant. The following ingredients constitute the percentage composition of the ashes of the above crops:—

	Iron Oxide.	Potash.	Soda.	Lime.	Magnesia.	Silica.	Phosphoric Acid.	Sulphuric Acid.	Chlorine.
[2] Entire Wheat Plant .	2·190	11·670	2·590	3·600	5·530	64·990	4·490	4·050	0·890
[2] Wheat (grain)	1·124	32·392	2·497	10·668	3·784	1·964	45·269	1·294	1·007
[2] Turnip (roots)	1·321	50·124	3·621	13·024	2·000	1·215	16·412	6·954	6·328
[2] Turnip (leaves)	0·986	27·921	7·024	35·620	4·199	2·134	4·218	11·999	5·898
[2] Potato (tubers)	5·150	53·800	0·710	3·020	7·940	5·000	15·630	5·210	3·500
[2] Potato (haulm)	1·100	28·990	15·520	17·070	7·900	3·640	7·840	5·640	12·300

[1] Dr. A. B. Griffiths' Analyses (*Journal Chemical Society*, 1883–7).
[2] *Ibid.*

These tables show that wheat requires nitrogenous manures. Upon analysis it yields from 3·5 to 14·7 per cent. of nitrogenous substances (albuminoids). Before maturity a liberal dressing of *soluble* phosphates would prove highly beneficial, for the ash of wheat (grain) contains no less than 45¼ per cent. of phosphoric acid.

Turnips, on the other hand, require only a small supply of nitrogen, but large quantities of phosphoric acid and potash; while *potatoes* require potash manures, for the ash of the tuber contains nearly 54 per cent. of that ingredient.

Though wheat, turnips, and potatoes require (for their growth) large supplies of nitrogen, phosphoric acid, and potash respectively, the importance of the minor constituents of their ashes must not be overlooked. All the ash constituents are indispensable for the growth of healthy crops.

Some of the ingredients found in plants are obtained from the atmosphere, while others are absorbed from the soil during growth. Thus, the carbon forming the woody structures of plants is obtained from atmospheric carbonic acid. This gas contains carbon, and is represented by the chemical formula CO_2. This formula shows that carbonic acid gas is composed of carbon and oxygen in the atomic proportion of 1 to 2 (*i.e.* one atom of carbon linked to two atoms of oxygen). The following table represents the constituents of plants derived respectively from the air and soil:—

Constituents of Plants.		From Air (A).	From Soil (S).
Albuminoids. Amides and Alkaloids. Carbo-hydrates, Fat, etc. Organic Constituents.	Carbon	A	—
	Hydrogen	—	S
	Oxygen	A (partly) [?]	S
	Nitrogen	A (partly) [?]	S
	Sulphur	—	S
	Phosphorus	—	S
Ash, Mineral, or Inorganic Constituents.	Iron Oxide	—	S
	Potash	—	S
	Soda	—	S
	Lime	—	S
	Magnesia	—	S
	Silica	—	S
	Phosphoric Acid	—	S
	Sulphuric Acid	—	S
	Chlorine	—	S

From the above table the farmer will see how important it is that all cultivated *soils* should contain the necessary foods for plant nutrition and growth.

It has been often argued that most soils contain a plentiful supply of the minor constituents found in the ashes of plants. Therefore it is unnecessary to add the *minor* plant foods to the soil. M. Ville states that only nitrogen, potash, lime, and phosphoric acid need be added to any soil, in the form of manure. This, in our opinion, is an erroneous idea. Many of the minor constituents may possibly be present in more than a sufficient quantity of any crop's ultimate total requirements; yet the crop does not produce a full yield, and is often diseased. In most soils these constituents are to be found in the form *of insoluble* compounds, which are only partially rendered soluble during the life of ordinary farm crops. It must

not be forgotten that liquid and gaseous matters are alone admitted into the interior of plants. Solids are never absorbed by the rootlets of plants.

The rootlets of most plants secrete a slightly acid substance which dissolves the otherwise *insoluble* constituents of the soil. But, as farm crops only live for a few months at the utmost, it is a policy which pays in the long run for the farmer to help nature by adding not only such manures as phosphates, nitrates, and potash, but the *minor constituents* in the form of soluble compounds.

There is little doubt that many farm crops are miserable failures, because the soil is incapable of properly nourishing them.

By way of example we will take *iron* as a minor constituent of the soil. Suppose the soil contained 4 to 5 per cent. of iron[1] as *in*soluble compounds, also that the crop grown upon such a soil required for its proper growth and nutrition 4 per cent. of iron, but by means of the acid secretion of the rootlets only *one* per cent. of this element was rendered soluble and taken into the plant during its period of growth, such a crop could not possibly produce a full yield. The farmer, in this case, may have manured his soil with superphosphates, etc., yet the crop is a failure. This example is no theoretical idea, but the outcome of extensive field experiments. The author of the present work grew, during the season of 1883, bean crops upon a soil of *good quality* and of known composition. This soil contained 3·96 per cent. of *iron* oxide (*insoluble*). Two plots of land (one acre each) were marked off. One plot was manured with ½ cwt. of

[1] Iron is generally found in most soils, in the form of insoluble compounds.

iron sulphate (*soluble*). The other plot was not manured with "soluble iron." Upon each plot was set the same number of bean seeds. At the harvest the following results were obtained :—

	Crop A.		Crop B.	
	Plot manured with soluble iron.		Plot not manured with iron.	
	Weight when gathered.	Weight when dry.	Weight when gathered.	Weight when dry.
Total weight of crop (grain and straw) . .	6,783 lbs.	5,882 lbs.	5,210 lbs.	4,487 lbs.
Yield of grain	56 bushels.		35 bushels.	

On submitting the ashes of these plants to chemical analysis, it was found that those grown *with* the iron manure gave 4·2 per cent. of iron oxide and an increased yield; while the plants grown *without* this substance yielded only 1·06 per cent.[1]

This is a fair illustration of the importance of what is known in scientific agriculture as the "*law of minimum.*" A soil destitute of any mineral ingredient requisite for plant life may become more or less barren, since it is the minimum of any one essential ingredient, and not the maximum of others, which is the measure of fertility. And "a soil may contain an abundance of potash, lime, phosphoric acid, iron, etc., and yet be almost barren if these substances exist as insoluble compounds."[2] In the

[1] Dr. Griffiths, in *Journ. Chem. Soc.*, 1884, p. 71.
[2] "A Treatise on Manures, p. 13.

words of the late Dr. Anderson: "If, for example, a soil contains a sufficient quantity of potash to yield, say, twenty full crops of wheat, and of the other constituents of that plant enough to yield forty crops, the excess of the latter will be unavailing, and the soil would be exhausted by twenty crops. If, now, we added to such a soil a supply of potash, it would again become capable of producing a crop, and would go on doing so until some other substance had been entirely consumed, when it also would have to be added; and so on until, all being removed, the soil would at length end in a complete infertility, which would duly be retarded, and not prevented by this mode of operation. To maintain during an *unlimited* series of years an uniform amount of produce, it would be necessary to add, *year by year*, a quantity of the elements of plant-food equal to that which the crop removes; and the necessity for doing this is so obvious that it cannot be controverted, and may be safely asserted, that it is a point on which all scientific and practical men are entirely at one."

"This being the principle on which the *exhaustion of the soil* is to be avoided, we have only to carry it out a little further to draw the conclusion, that if we give it a larger quantity of the elements of plant-food than is requisite to replace what has been removed, its productive capacity must be increased, and it will become capable of yielding a larger crop than it did in its original state. This is, in fact, *the foundation of the use of manures*."

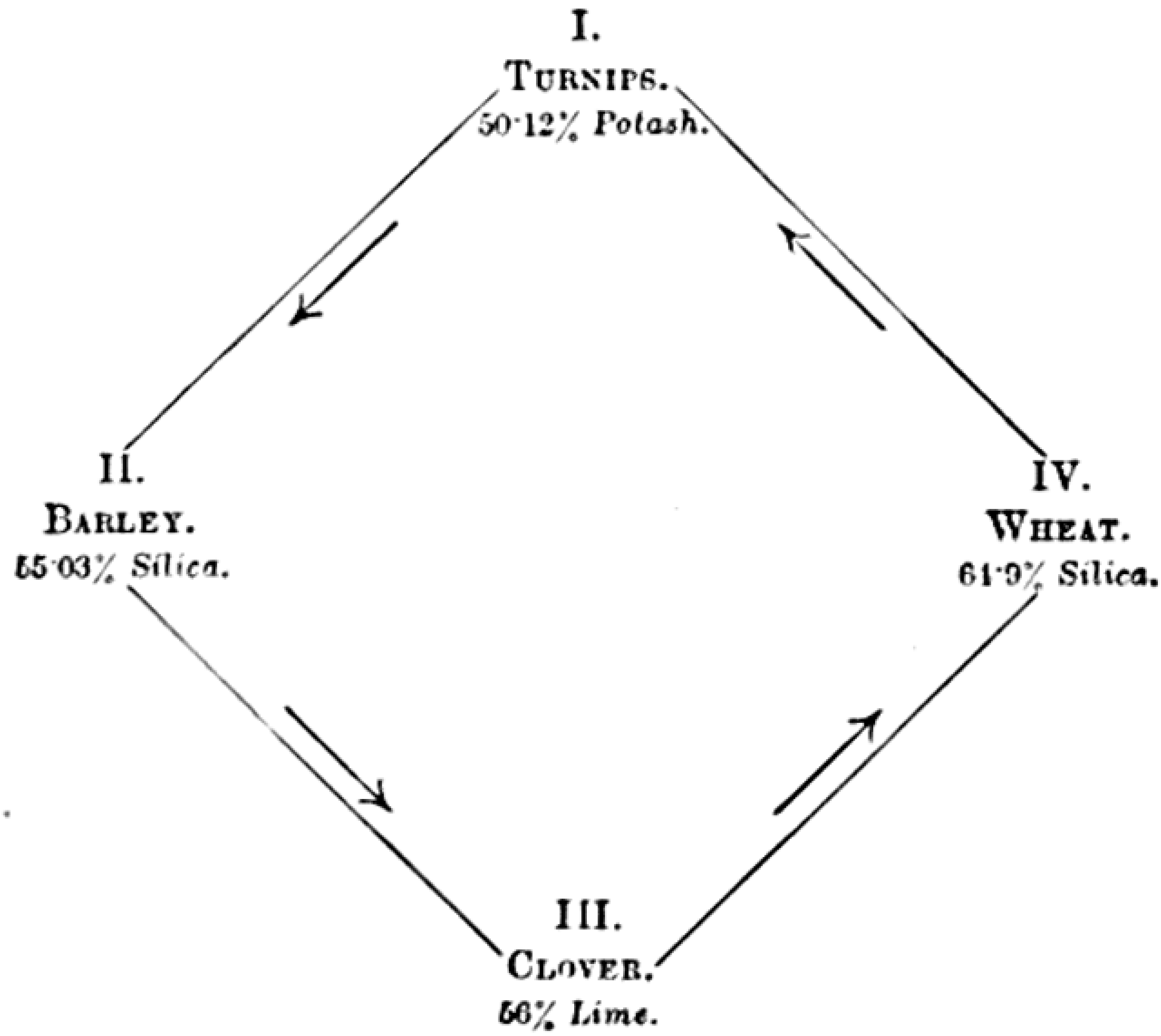
The next table gives the composition of various barren and fertile soils.

BARREN AND FERTILE SOILS.

	Barren Soils.			Fertile Soils.		
	Peaty.	Sandy.	Peaty.	Clayey loam.	Black sandy mould.	Loam.
Silica	4·18	96·00	7·96	80·75	67·29	58·14
Organic matter .	89·14	1·499	90·44	4·92	9·30	9·11
Ferric oxide . .	0·23	2·000	0·12	3·93	2·13	4·20
Manganese oxide .	—	Trace	—	—	—	—
Alumina . . .	0·58	0·500	0·63	2·92	10·25	17·69
Magnesia . . .	0·17	Trace	0·08	0·50	0·96	1·05
Lime carbonate .	—	—	—	3·25	—	—
Lime sulphate .	—	—	—	0·26	—	—
Potash and soda .	—	—	0·01	0·36	—	—
Water	4·55	—	—	2·73	3·42	2·47
Lime	1·15	0·001	0·55	—	1·34	2·27
Potash	Trace	Trace	—	—	2·23	2·73
Soda	—	Trace	—	—	1·98	1·39
Sulphuric acid .	—	Trace	0·19	—	0·11	0·14
Phosphoric acid .	—	Trace	0·02	0·38	0·31	0·27
Chlorine . . .	—	—	—	—	0·68	0·54
	100·00	100·00	100·00	100·00	100·00	100·00

During the growth of farm crops, some absorb large quantities of *soluble* silica, while others require very little of that compound. If a crop requires a comparatively large amount of potash, it should be followed by one requiring for its growth only a small amount of that substance. By this method a certain amount of potash comes into the soil, through the disintegration of the rocky masses beneath the subsoil.

The following diagram shows the *chief* mineral ingredients removed from a soil during a Norfolk rotation:—



The above figures represent the percentages of the ingredients in *the ashes* of the plants (*i.e.*, the percentage of the "*maximum*" ingredient, in each case, absorbed from the soil). It will be seen that a crop of turnips extracts a large amount of potash from the soil. For economic farming turnips ought to be followed by a crop requiring only a small amount of potash. In the Norfolk rotation turnips are followed by barley, which absorbs chiefly silica; and this crop is followed by clover, which is sometimes called a "lime plant."

Although "rotations" are useful adjuncts in any system of agriculture, yet the farmer must never forget that even "rotations" and ordinary farmyard manure alone are incapable of preserving the fertility of any soil.

In conclusion, the fertility of a soil can only be re-

tained by the farmer thoroughly understanding the undermentioned laws, and applying them in his system of husbandry :—

(1) "A soil can be termed fertile only when it contains all the materials requisite for the nutrition of plants in the required quantity, and in the proper form."

(2) "With every crop a portion of these ingredients is removed. A part of this portion is again added from the inexhaustible store of the atmosphere; another part, however, is lost for ever if not replaced by man."

(3) "The fertility of the soil remains unchanged if all the ingredients of a crop are given back to the land. Such a restitution is effected by *manure* and by the atmosphere."

(4) A soil may contain an abundance of potash, lime, phosphoric acid, iron, etc., and yet be almost barren, if these substances exist as *insoluble* compounds.

(5) A fertile soil must be of such a texture as to admit free access of air, although at the same time it must not be too porous, but firm enough to afford proper support to growing crops.

(6) The soil must be capable of retaining a certain amount of water, yet porous enough to allow an excess to drain away.

(7) A certain quantity of organic matter must be present, for it causes the disintegration of the soil, and renders it more friable. It yields nitrogenous matters to the crops, and has the power of retaining certain soluble substances in light soils.

There must not be *an excess* of organic acids present, or "sour" land is the result.

(8) "The manure produced in the course of hus-

bandry is *not* sufficient to permanently maintain the fertility of a farm; it lacks the constituents which are annually exported in the shape of grain, hay, milk, and live stock."[1]

The reason why our soils require the addition of manures will now be apparent, for "profitable farming necessitates the maintenance of the land in an *increasing* rather than a decreasing state of fertility."

[1] Cake manure is *not* included here.

CHAPTER III.

ORGANIC MANURES.

IN the words of the late Mr. Baldwin, "we have for centuries subjected the soil to a slow system of spoliation, we have weakened the links which complete the circle of fertility; and if we blindly persevere in the same course, the chain will sooner or later snap, as surely as effect follows cause." To arrest this spoliation, therefore, and restore the land to fertility, it is of paramount importance that the practical agriculturist should have a thorough knowledge of manures and their uses.

The object of manuring is to replace in the soil those substances which have been extracted from it during the growth of crops. If these substances are not replaced, how can the land remain fertile? Some farmers have rather crude ideas of the use of manures. To these, we say, study the composition and nature of your soil, and the requirements of each crop grown, and it will be evident that phosphates, nitrates, sulphates, etc., required for the growth and maturity of plants, must be present in all cultivated soils. If farm crops are continually extracting these substances from the soil, common sense dictates that we must replace them if fertility is to be preserved. The soil does not contain an inexhaustible supply of these substances. Therefore, it

becomes a necessity that the use of different kinds of manures (or soil fertilisers) is the only means of keeping the lands in a fertile condition.

It would be better for British agriculture if farmers paid more attention to the subject of manuring. "Would, indeed, that the agricultural could copy a little more from the manufacturing industry than it appears to be doing! How much it has to learn in dealing with diversities of soil, in the reclamation of waste lands, in the introduction of machines and implements of husbandry, *in the use of manures*, and above all in the economy of labour and the application of scientific principles in the management of farms!" [1]

The various manures or plant-foods used in this and other countries of which we now propose to treat, may be classified [2] as follows:—

(*a*) Organic manures.
(*b*) Artificial manures.
(*c*) Special manures.

These three divisions may be subdivided according to the following table:—

[1] Prof. Leone Levi's "Work and Pay," p. 19.

[2] The above classification is only a conventional one, for "it is hard to draw the line between organic and artificial manures;" and as no fixed rule can be given for classifying them, any system adopted is simply a matter of opinion.

TABLE OF MANURES.

Organic.	Artificial.	Special.
Farmyard manure	Raw bones	For roots
Human excrements	Boiled and steamed bones	,, potatoes
Urine or liquid manure	Bone black	,, turnips
Sewage manure	Bone-ash	,, grass
Poudrette	Bone superphosphate	,, cereals
Composts	Bone-ash superphosphate	,, mangels
Sheep-fold manure	Guanos	,, oats
Blood manures	Rodunda phosphate	,, beans, etc.
Leather	Coprolites	
Hides, horn, hair, etc.	Mineral phosphates	
Woollen refuse and shoddy	Thomas phosphates	
Oil-cakes	Superphosphates	
Brewers' grains	Dissolved wool	
Bran of wheat	Dissolved Peruvian guano	
Fish refuse	Retrograde and precipitate phosphate	
Seaweeds	Ammonium sulphate	
Green manures	Ammoniacal liquor	
	Spent iron oxide	
	Nitrate of soda	
	Nitrate of potash	
	Soot	
	Kainit and Carnellite	
	Vegetable ashes	
	Norwegian fish potash guano	
	Lime	
	Gypsum	
	Salt and sodium salts	
	Sulphate of iron	
	Sulphate of magnesia	
	Silica	

The next classification is based upon that of Drs. Stöckhardt and Voelcker, the arrangement being made according to the composition of the manures, and the various plant-foods they are capable of adding to the land.

CLASSIFICATION OF MANURES.

(Altered from Stöckhardt and Voelcker.)

	Nitrogenous.	Carbonaceous.	Potash.	Soda.	Phosphoric acid.	Various.	Calcareous.	Silicious.
Contain ammonia and act quickly.	Ammoniacal salts	Farmyard dung	Kainit	Salt	Bones	Gypsum	Lime	Silica
	Peruvian guano, soot	Straw	Carnellite	Nitrate of soda	Thomas phosphate	Iron sulphate	Marl	Coal ashes
	Animal substances (blood, flesh, wool, etc.)	Leaves	Malt-dust	Urine	Guanos	Magnesium sulphate	Gypsum	Farmyard dung
	Ammoniacal liquor	Sawdust	Urine	Soap-boilers' refuse	Coprolites		Coal ashes	Sand
	Putrid urine	Green manure	Wood ashes	Sodium sulphate	Mineral phosphates		Gas lime	Straw
	Short dung	Peat	Leaves	Sodium carbonate	Animal matter		Carbonate of lime	Peat ashes etc.
Tolerably quick in action.	Horn shavings		Green manure		Dung		Thomas phosphate	
	Bones, dissolved, etc.		Burnt clay		Straw, etc.			
	Oil-cakes, malt-dust		Fish potash guano					
	Fresh urine							
Decompose with difficulty.	Half-inch bones							
	Woollen rags							
	Long dung							
Containing nitric acid, quick acting.	Saltpetre							
	Nitrate of soda							
	Nitre earth							

Among the artificial manures, guano, nitrate of soda, and ammonium sulphate are the most important; although all the necessary plant-foods must be present in cultivated soils if the crops are to attain a healthy growth.

The accompanying map (*Frontispiece*) shows the various countries of the world containing *natural* deposits of nitrogenous, phosphatic, and other manures.

It is impossible, within the limits of this small treatise, to give a full description of the properties and manurial value of all the fertilizers mentioned in the preceding tables. Ample information will, however, be given concerning the most important manures; the minor fertilizers and their uses will have less attention.[1]

The first manure to be considered is farmyard manure.

(1) Farmyard Manure.

Farmyard manure, regarded by farmers and others as the most important fertilizer for all cultivated soils, is a mixture of the solid and liquid excrements of farm animals with straw, moss, etc., used as litter.

This manure is erroneously supposed to contain *all* the necessary plant-foods required for the growth of crops. If it contains "all the fertilizing constituents essential to the growth and fructification of plants," why do farmers use guanos, phosphates, nitrates, etc.? Surely these artificial manures are too costly to apply to the land if farmyard manure is capable of producing healthy as well as "full crops." It is, however, known that the land cannot retain its maximum of fertility if farmyard dung is the only manure used. In the words of M. Ville, "the farmer who uses nothing but farmyard manure exhausts his land."

[1] For fuller information see the author's "Treatise on Manures" (Whittaker & Co.).

The use of farmyard manure alone has a tendency to withdraw from the soil a considerable amount of phosphate of lime and nitrogen. For a large amount of phosphate of lime and nitrogen (originally in the soils and afterwards in the food of farm animals) is used up in the formation of bones, nerves, and muscles of the animals producing the manure. The nitrogen, phosphates, etc., sold off the farm in the form of flesh, bones, and milk, are never returned to the soil in the excrements of farm animals. Therefore it becomes a matter of the utmost importance that *other* fertilizers, besides that produced in husbandry, must be returned to the soil, if our soils are to remain fertile.

Farmyard manure has no constant composition. Its composition varies with the class and age of the animal producing it. The quality of their foods, method of preparing the manure, and the nature of the litter, all influence the composition of farmyard manure.

During the fattening of farm animals (*i.e.*, when they are fed upon oil-cake, etc.), the manure is always richer than at other times.

In every 1,000 lbs. of linseed cake used as food, 66 lbs. of nitrogen, 31 lbs. of phosphoric acid, and 15 lbs. of potash are returned to the soil in the form of manure. With beans as food, 1,000 lbs. return in the excrements 41 lbs. of nitrogen, 11½ lbs. of phosphoric acid, and 12 lbs. of potash. With 1,000 lbs. of turnips as food, only 2 lbs. of nitrogen, ½ lb. of phosphoric acid, and 3 lbs. of potash are returned as manure.

Oil-cakes yield the richest manures, then come leguminous crops, next cereals, and finally roots (like potatoes, mangels, and turnips).

Professor H. Tanner, F.C.S., quotes the following analyses of fresh and rotten farmyard manure:—

COMPOSITION OF FARMYARD MANURE.

	Fresh.		Rotten.		
	No. of lbs. in each ton.	Value.	No. of lbs. in each ton.	Value.	Price.
		s. *d.*		*s.* *d.*	Per lb.
Water	1482¼	—	1689¼	—	—
Soluble organic matter .	55½	2 0	83	4 0	Ammonia 6*d.*
Soluble inorganic matter: Soluble silica . .	5¼	—	5¾	—	—
Phosphate of lime	6¾	0 5	8½	0 6½	0 0¾*d.*
Lime	1½	—	2½	—	—
Magnesia . . .	¼	—	1	—	—
Potash	12¾	3 3¾	10	2 9	0 $3\frac{3}{10}$*d.*
Soda	1¼	—	½	—	—
Sodium chloride .	¾	—	¾	—	—
Sulphuric acid. .	1¼	—	1¼	—	—
Carbonic acid and loss.	4¾	—	2¾	—	—
Value of soluble matter .	—	5 8¾	—	7 3½	
Insoluble organic matter	577	6 9	287¼	4 3	Ammonia 6*d.*
Insoluble inorganic matter: Soluble silica . .	21¾	—	32	—	—
Insoluble silica .	12½	—	22½	—	—
Oxide of iron and phosphates . .	13½	0 6½	21¼	0 8¾	0 0¾*d.*
Lime	25	—	37½	—	—
Magnesia . . .	3¼	—	2	—	—
Potash	2¼	0 7½	1	0 3¼	0 $3\frac{3}{10}$*d.*
Soda	½	—	¾	—	—
Sulphuric acid. .	1¼	—	1½	—	—
Carbonic acid and loss. . . .	10¾	—	29	—	—
	2240	7 11	2240	5 3	
Value of insoluble matter	—	7 11	—	5 3	
Value of soluble matter .	—	5 8¾	—	7 3½	
Total value of a ton of manure	—	13 7¾	—	12 6½	

From the above analyses, one ton of well-rotten farmyard manure contains 15 cwts. of water, 4 cwts. of other materials, and only $47\frac{3}{4}$ lbs. of fertilizing ingredients. Therefore, the plant-foods contained in farmyard manure bear but a very small proportion to its mass.

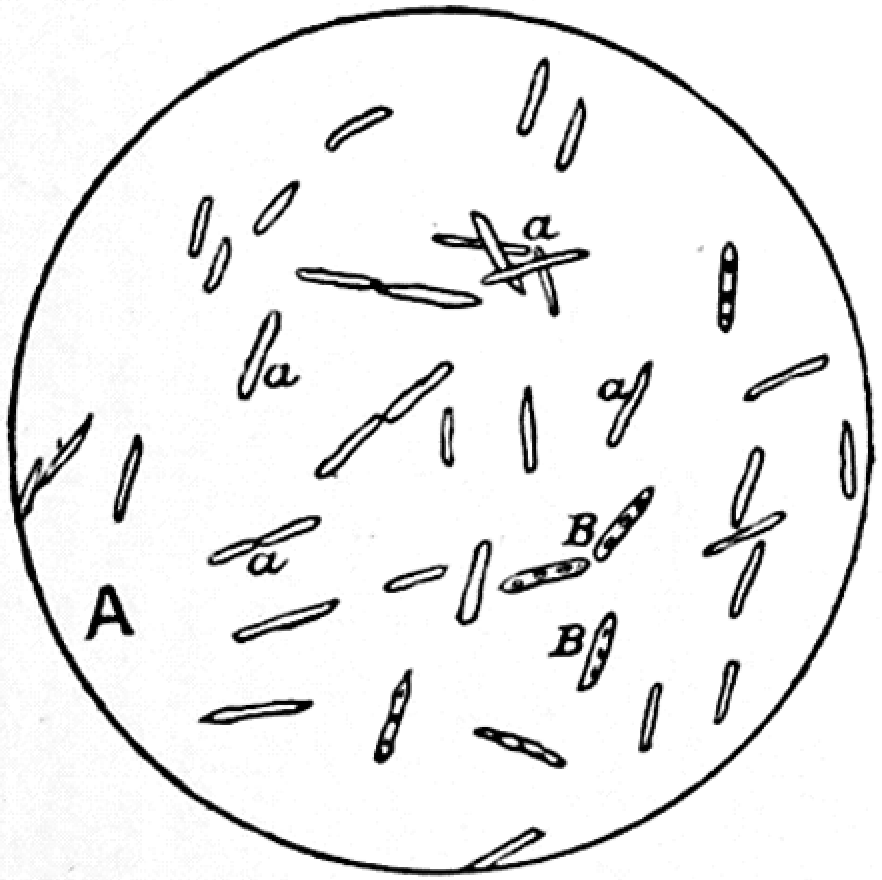
According to the above analyses, farmyard manure contains no less than 75 per cent. of water.

In the fresh state, farmyard dung contains only a small quantity of ammonia or nitrogen in a soluble condition. The nitrogen is chiefly in the form of organic matter, which is insoluble, therefore it cannot be absorbed by the rootlets of plants. Root-absorption only takes place when the substances are in the liquid or gaseous condition. No plant absorbs solid matter. On the other hand, well-rotten dung contains a certain amount of nitrogen in the form of ammonia, which is *soluble* in water, and is therefore ready to be taken up (after oxidation, etc.) by the rootlets of farm crops.

During the *fermentation* of farmyard manure various changes take place. The straw, vegetable matters, etc., along with the excreta, undergo a certain change brought about by the agency of microscopic organisms. This change is termed *nitrification*.

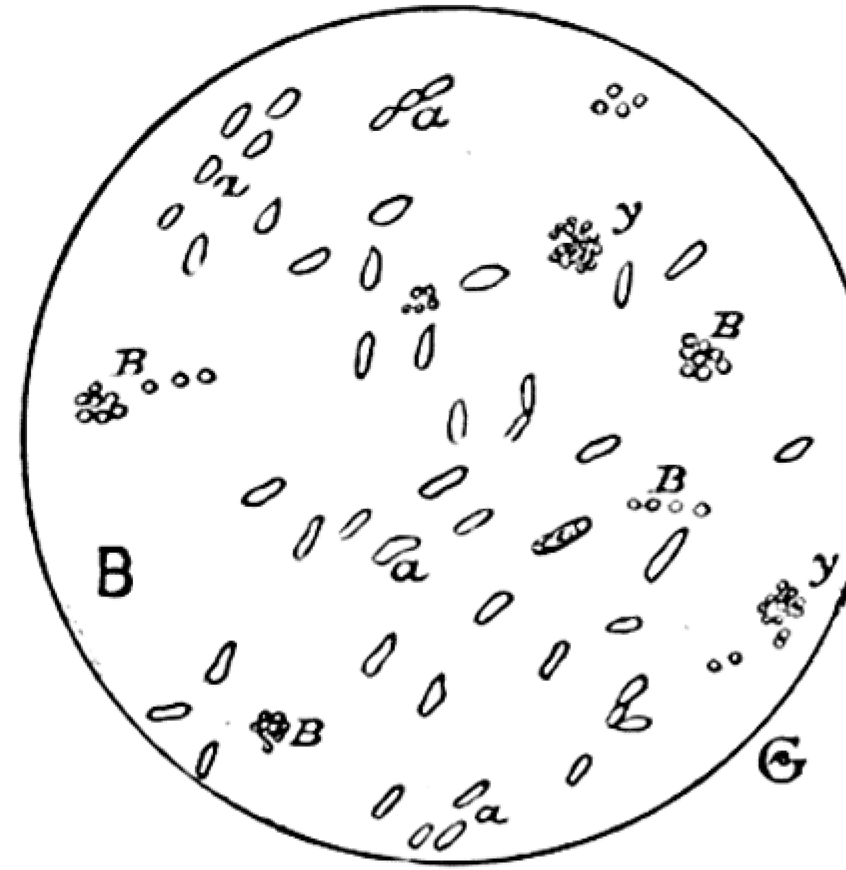
Nitrification is due to the life-work of certain micro-organisms present more or less in all soils. Amongst these *Bacillus tardecrescens*, *Bacterium ureæ* (Leube and Graser, in "Virchow's Archiv," vol. c. p. 555) [Fig. 2B], and *Bacillus fluorescens* [Fig. 2A], all nitrify organic matter (like urea), forming small quantities of nitrates.

Although the above micro-organisms are capable of nitrifying organic matter to a certain extent, the "organism [or organisms] which nitrifies *as soil nitrifies* has yet to be isolated" (Warington).



A = Bacillus Fluorescens.

α = The slender cells of the microbe.
β = Spore-formation.
In tube cultivations, growing in gelatine, the microbes produce a greenish appearance—forming the "pyocyanin" of Dr. Gessard.



B = Bacterium Ureæ.

α = The microbe.
β = Masses of cocci. The microbe "splits up by division into chains of cocci, and the latter are finally set free. The cocci increase further by subdivision, and a jelly-like membrane develops around them." (γ)

One of the first products formed during the nitrification of organic matter is ammonia. The ammonia is then oxidised, and becomes nitric acid. The nitric acid combines with certain bases (like potash, soda, and lime) already in the soil, forming nitrates which are soluble in water, and thereby become valuable plant-foods.

Other changes, besides nitrification, occur in the organic matter of farmyard manure during its fermentation. One of these is the oxidation of the carbohydrates (*i.e.*, the woody portion, etc.). The carbon of these substances is converted into carbonic and organic acids. These acids are neutralized by the potash, lime, etc., of the soil, at the same time producing active and dormant plant-foods.

"The temperature of fermentation should not be allowed to rise in the centre of the heap above 150° F., as loss of valuable ammonia is the result. The temperature (ascertained by an ordinary thermometer) should be regulated by water, or better still, liquid manure (viz., urine, or stable runnings). The heap should not be drenched, or the valuable nitrogenous compounds will run into the drains. A strong odour coming from the heap shows that a wasteful fermentation is going on. . . . If the farmyard manure contains too small a proportion of litter (straw, etc.), the urea contained in urine is quickly converted into ammonium carbonate,"[1] which is a very volatile compound. The volatile ammonium carbonate may be "fixed" by watering the manure heap with a solution of commercial iron sulphate. The author has shown that iron sulphate has the power of retaining ammonia in soils (*Journal Chemical Society*, 1883–87); and Mr. T. C. Fletcher, in his "Scientific Farming made Easy," "re-

[1] The author's "Treatise on Manures," pp. 34, 35.

commends that sawdust moistened with a solution of iron sulphate (1 cwt. of iron sulphate to 100 gallons of water) should be spread on the floor of the stable, cowhouse, piggery, etc."

By this means the ammonium carbonate is converted (by the iron sulphate) into a double sulphate of ammonium and iron, which is non-volatile.

THE LITTER used in the "court yards" is an important item in the preparation of farmyard manure. Straw and moss are the two principal forms of litter used in this country. In Germany, peat-moss and bracken ferns [1] are used (with considerable success) as litter. Fern litter is also used in the New Forest.

The nature of the litter effects the composition ot the farmyard manure.

Certain experiments show that moss litter yields a far better manure than the straw of wheat, barley, or oats. All crops requiring supplies of nitrogen yield fuller and better produce when grown with moss-litter manure than with straw-litter manure. Moss makes a better manure for light sandy soils, and the after effects are greater than when straw is employed.

Moss contains nearly 2 per cent. of nitrogen, while the straw of oats, wheat, and barley does not contain $\frac{1}{4}$ per cent. of this fertilizing element.

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[1] In the time of the Romans *ferns* were largely used as litter. Virgil mentions the use of fern and straw litters for sheep. He says in his "Georgics" (Liber III.):—

> "Incipiens stabulis edico in mollibus herbam
> Carpere oves, dum mox frondosa reducitur æstas;
> Et multa duram stipula filicumque maniplis
> Sternere subter humum, glaciesne frigida lædat
> Molle pecus, scabiemque ferat turpesque podagras."

It must be remembered that too much straw, moss, etc., lessens the manurial value of the excreta of farm animals; on the other hand, there must be sufficient litter to absorb the liquid excrements, "which contain the largest percentage of nitrogen, and nearly all the potash of the two classes of excrements. The manure should not be kept too moist, as valuable ingredients are apt to pass away by drainage; and too much moisture prevents fermentation, which is essential to bring about the necessary chemical changes in the nitrogenous constituents of the manure" ("Treatise on Manures").

The Management of Farmyard Manure.—According to a certain writer, "the methods in use for the saving and treatment of farmyard manure are characterized by great wastefulness, and a thorough ignorance of, or at least indifference to, the principles which regulate them."

One of the oldest methods for the treatment of farmyard manure is the well-known "heap" method. The manure is piled in heaps in the corners of fields.

Sometimes these heaps are covered with soil, the object being to prevent volatilization of ammonia and to keep out rain. This is the worst of all methods of keeping manure.

The method is largely practised in this country and in France, especially in Northern Normandy. Northern Normandy is more agricultural than the southern part of the province, where the numerous hills and dales are covered, more or less, with "green pastures."

If it is necessary to cart the manure direct to the fields, "it is better to spread it upon the soil at once." By this means active fermentation and the temperature of the manure are reduced. The manure itself absorbs any ammonia already formed; therefore, loss of this all-important fertilizer is reduced to a minimum. But

practice and science "go hand in hand together" in pronouncing that ploughing in the manure *at once* is the best method to adopt, especially where the soils are of a light sandy nature.

It is important for the farmer to retain within the fermenting manure as much ammonia as possible. Although farmyard manure is stated to be a "general manure," it is essentially a nitrogenous manure. MM. Boussingault and Payen state that the value of farmyard manure depends upon the quantity of nitrogen it contains.

When farmyard manure is made under cover (*i.e.*, in covered pits made water-tight), the maximum amount of manurial value is obtained from it. "Box-made manure" is richer in nitrates and ammonia than farmyard manure made in the open, and is stated to be worth half as much again as ordinary farmyard dung.

Lord Kinnaird made the following field experiments with "box manure" and ordinary farmyard dung. "A field of potatoes was manured in one part with the manure taken from a 'covered,' and in another part with manure taken from an 'open' or exposed dung-heap; the produce of potatoes being determined, the whole of the land was then sown down with wheat, and top-dressed in the spring with 3 cwts. of Peruvian guano per acre."

The results were as follows:—

BOX MANURE *VERSUS* ORDINARY FARMYARD MANURE.

	Yield with Box Manure.	Yield with Ordinary Farmyard Manure.	Difference.
Potatoes . .	11 tons 15 cwts.	7 tons 12 cwts.	4 tons 3 cwts.
Wheat, grain .	54 bushels	42 bushels	12 bushels
Wheat, straw .	215 stones	156 stones	69 stones

These results speak for themselves.

It is a mistake for farmers to suppose there is no appreciable loss of fertilizing matter in farmyard dung when carted, or heaped, or spread upon the land.

M. Payen recommended farmers to mix lime with *fresh* dung. By this means, loss of ammonia during fermentation is prevented, lime being a "fixer" of ammonia. Three or four per cent. of lime is amply sufficient for this purpose. Lime must only be added to *fresh* dung, for in this state the dung contains but a small quantity of ammonia. Its nitrogen is in the form of non-volatile organic compounds.

On the other hand, if added to *rotten* dung, lime liberates the ammonia, resulting in loss.

Salt, iron sulphate, peat, charcoal, and gypsum, are all useful agents for "fixing" ammonia in farmyard manure. Soil also forms a good "fixer" of ammonia in the manure heap. "We have been asked where a farmer is to get the earth to cover his heaps. It may be answered, keep your roads scraped when they get muddy on the surface during rainy weather—in itself good economy—and leave this in small heaps beyond the margin of your roads. This, in the course of the year, will be found an ample provision for the purpose, for it is unnecessary to lay on a coat more than one or two inches in thickness, which should be done when in a moist state. The soil left on cleaning the roots for the stock at the stores [if this has not already been done in the fields] will contribute much for this purpose. Farmers who have not been in the habit of bestowing care on the manufacture and subsequent preservation of their manure, and watching results, have no conception of the importance of this" (Lawrence).

Properties of Farmyard Manure.

Besides its manurial value, farmyard manure has the following properties:—

(*a*) Farmyard manure *warms* the land.

(*b*) It retains ammonia and moisture in light soils.

(*c*) By retaining *moisture* in soils, it indirectly retains soluble mineral plant-foods in soils, these substances forming the constituents of the water contained in soils.

(*d*) It renders the soil more friable.

(*e*) During its decomposition, the gases, etc., produced, convert the *dormant* (inactive or insoluble) plant-foods of the soil into *active* (soluble) ones.

(*f*) Farmyard manure is a medium in which fungoid diseases (like the potato disease, wheat-mildew, etc.) are capable of hibernating for months without losing their vitality.[1]

Although farmyard manure possesses many "virtues," we again repeat it must not be the only manure used on the farm.

Application of Farmyard Manure.

The time and mode of applying farmyard manure depend upon the crop and the nature of the soil.

There is very little loss (through rains) when farmyard manure is applied in the autumn, especially on clayey land. Autumn manuring brings the land into good condition.

(*a*) For WHEAT crops, which follow clover (as in the Norfolk or four-course rotation), the quantity of farmyard manure applied should be about 12 tons per acre. In

[1] Dr. Griffiths, in *Chemical News*, vol. xlix. p. 270.

the United States of America, 200 lbs. of superphosphate of lime are used as a dressing (in addition to the farmyard manure) for winter wheat. The American system yields from 15 to 40 bushels of grain per acre.

The rotation practised in "the States" is the following: Indian corn, barley (or oats), wheat, and seeds (clover and timothy grass for hay, or for feeding).

Wheat, as a rule, grows best on strong soils.

(*b*) For BARLEY crops, the quantity of manure applied should be about the same as for wheat.

The best soil for the growth of this crop is a mellow loam. When grown on *sandy* or *calcareous* soils, the following top dressing—

$$\begin{cases} \text{1 cwt. of nitrate of soda,} \\ \text{1 \quad ,, \quad common salt,} \end{cases}$$

per acre, has proved most beneficial for barley.

(*c*) For BEANS, after corn, between 16 to 20 tons of farmyard manure per acre should be ploughed into the land. Bean crops thrive best in strong calcareous soils. Hence lime should form an essential ingredient of every soil in which beans are cultivated. Beans are benefited by top-dressings of "artificials."

(*d*) For TURNIPS, about 10 to 12 tons of farmyard dung per acre are required. Turnips are greatly benefited by using phosphatic manures. "Lawes' Turnip Manure" contains from 22 to 24 per cent. of soluble phosphates, 6 to 8 per cent. of insoluble phosphates, and from 1 to $1\frac{1}{4}$ per cent. of ammonia. This manure is used at the rate of 4 to 6 cwts. per acre at the time of drilling the seed.

"The important part which manures exercise in the growth of the turnip is now generally recognised; but farmers do not always bestow enough attention to the selection of manures, and to the application of them in

proportionate mixtures to suit the requirements of the soils and of the varieties of turnips grown. In cultivating swedes, a portion of nitrogen should be present in the manure, a less quantity in cultivating yellow turnips, and in cultivating white turnips nitrogen may be wholly dispensed with, except on soils of a heavy argillaceous character, or on moorish soils in low manurial condition."

Farmers following the directions given for manuring these important root crops should vary the proportion of manures to suit the composition and nature of the soil and the climatic conditions of the neighbourhood.

MANURES FOR TURNIPS.

Manure Constituents.	For Swedes (per acre).		For Yellow Turnips (per acre).		For White Turnips (per acre).	
	Applied in Autumn.	Not applied in Autumn.	Applied in Autumn.	Not applied in Autumn.	Applied in Autumn.	Not applied in Autumn.
Cake-dust . . .	2 cwts. or	3 cwts.	1 cwt.	2 cwts.	1 cwt.	2 cwts.
Peruvian guano .	1½ cwt.	—	—	—	—	—
Superphosphate of lime . . .	2 cwts.	3 cwts.	2 cwts.	2 cwts.	2 cwts. or	2 cwts.
Bone-dust . . .	2 bush.	3 bush.	—	4 bush.	2 bush.	—
Kooria Mooria, or cheap guano .	—	—	2 cwts.	2 cwts.	1 cwt.	—

The above ingredients are made into mixtures forming what are known as "mixed" or "special" manures. The land should be previously manured with farmyard dung.

Turnips suffer from several forms of parasitic diseases, some producing a number of nodular outgrowths upon

the tubers, etc. The best known is the "*anbury*" (Fig. 3) or "*finger-and-toe*" (Fig. 4). This disease is produced by a fungus belonging to the *Myxomycetes*, and was called by M. Woronin *Plasmodiophora Brassicæ*.

There is little doubt that parasitic diseases "take hold" of turnip crops, in the first instance, through the crops being imperfectly nourished.

If farm crops do not receive a proper supply of all the requisite plant-foods, can we wonder that they become diseased? Sickly plants are just the media for the development and growth of parasitic fungi.

Let farmers look well to manuring their soils, and then the chances of farm crops becoming diseased would be reduced to a minimum.

The addition of lime, iron sulphate, etc., to soils, also the *weathering* of soils, are means of preventing disease.

The wise farmer will never use farmyard manure obtained from *turnip-fed cattle* for *turnip* crops. The excrements may contain the spores of fungal diseases, which might reproduce the diseases in the new turnip crop. The excrements of *turnip-fed* cattle might be applied with advantage to cereal crops. Turnip diseases do not attack cereals.

(*e*) For MANGEL-WURZELS from 14 to 16 tons of good farmyard manure per acre should be ploughed in the soil in the autumn. This to be followed by a top-dressing of 3 cwts. of guano and $1\frac{1}{2}$ cwt. of common salt to the acre. The above artificial manure is best sown broadcast. "Lawes' Mangel Manure" contains 20 to 23 per cent. of soluble and insoluble phosphates, and from 3 to 4 per cent. of ammonia. "If Lawes' Manure is used with the *water drill*, it should be sown down the rows upon the top of the dung; but if with the *dry drill*, it can be

drilled with the seed. If dung is used, 3 to 4 cwts. per acre will be sufficient; but without, it should be applied at the rate of not less than 5 to 6 cwts."

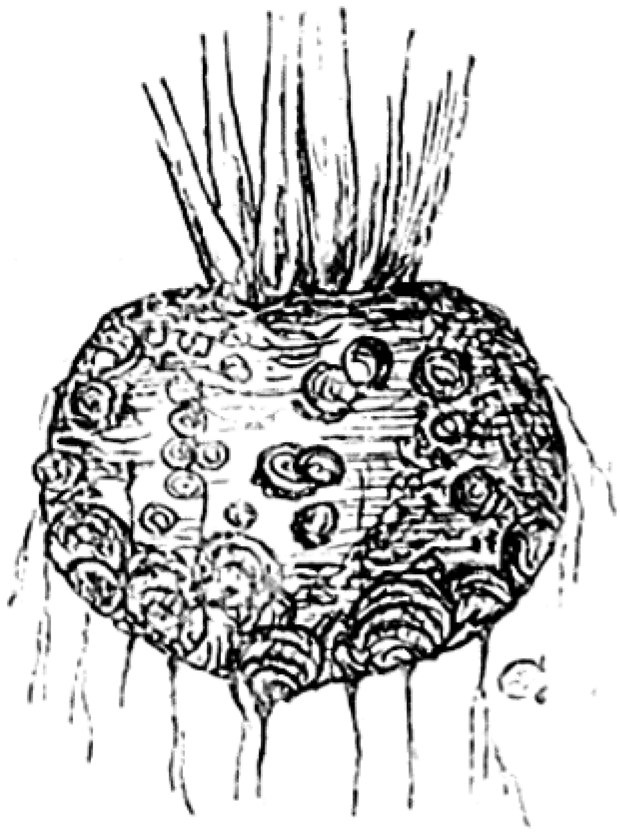

FIG. 3.—"ANBURY" AFFECTS THE TUBER ITSELF, COVERING IT WITH A NUMBER OF "WART-LIKE EXCRESCENCES."

The following manurial mixtures are recommended for mangels growing in different kinds of soils:—

MANURES FOR MANGEL-WURZELS.

	For *Sandy* soils.	For *Calcareous* soils.	For *Vegetable moulds.*	For *Heavy* soils.	For *Loamy* soils.
	Per acre.	Per acre.	Per acre.	Per acre.	Per acre.
Salt	1 cwt.	1½ cwt.	2 cwts.	2 cwts.	2 cwts.
Ammonium sulphate .	1 cwt.	—	—	—	—
Superphosphate of lime	2 cwts.	3 cwts.	4 cwts.	—	2 cwts.
Peruvian guano . . .	—	2 cwts.	—	4 cwts.	2 cwts.
Farmyard manure . .	—	—	—	Extra dressing	—

Mangels require a liberal supply of manures.

(*f*) For POTATOES, from 16 to 20 tons of farmyard manure are the usual quantities applied per acre. Some farmers have applied it at the rate of 20 to 30 tons per

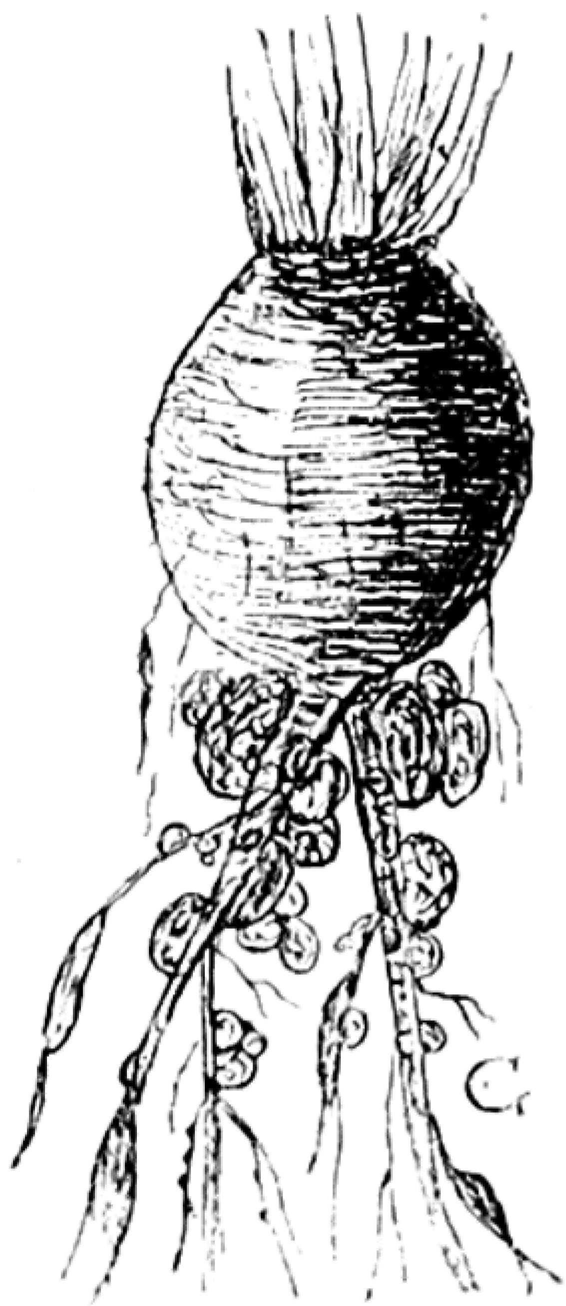

FIG. 4.—"FINGER-AND-TOE" PRODUCES NODULAR OUTGROWTHS ON THE ROOTS AND ROOTLETS.

acre. There is little doubt that the *heavy* manuring induces the development of the potato disease (*Peronospora infestans*).[1] Potatoes are greatly benefited by

[1] *The Chemical News*, vol. xlix. p. 279.

top-dressings of "artificials." The author[1] obtained excellent results with potatoes, using the following mixture:—

Per acre.
- 1 cwt. Kainit.
- 1 cwt. nitrate of soda.
- $\frac{1}{2}$ cwt. iron sulphate.
- 2 cwts. superphosphate of lime.

With this manure the yield was $8\frac{1}{2}$ tons of tubers per acre, while another plot unmanured yielded only 3 tons.

(*g*) On MEADOW LAND (for hay) from 10 to 16 tons of farmyard manure per acre should be applied in the autumn.

Meadow land is benefited by top-dressings of nitrate of soda, Peruvian guano, etc. The following mixtures form good manures for the production of hay:—

MANURES FOR MEADOW LAND (*for Hay*).

	For *Clayey* soils.	For *Sandy* soils.	For *Calcareous* soils.	For *Vegetable moulds.*	For *Loamy* soils.
	Per acre.	Per acre.	Per acre.	Per acre.	Per acre.
Guano	2 cwts.	1 cwt.	—	—	1 cwt.
Sodium nitrate . . .	—	1 cwt.	2 cwts.	2 cwts.	1 cwt.
Ammonium sulphate .	1 cwt.	—	1 cwt.	—	—
Salt	—	—	3 cwts.	2 cwts.	—
Superphosphate of lime	—	—	—	1 cwt.	2 cwts.
[2] Iron sulphate . . .	$\frac{1}{2}$ cwt.	$\frac{1}{2}$ cwt.	$\frac{1}{2}$ cwt.	$\frac{1}{2}$ cwt.	$\frac{1}{2}$ cwt.

Bone manures, as a rule, are not so valuable for meadows as for exhausted pastures.

[1] *The Journal Chemical Society*, 1886, pp. 114–120.

[2] To be applied as a top-dressing at the end of April, if the grass is cut towards the end of June.

(*h*) For SUGAR-CANE growing in the soils of the West Indies 20 tons of farmyard manure should be applied per acre. Sugar-canes are greatly benefited by dressings of "Ohlendorff's Special Cane Manure." This manure contains:—

Nitrogen = 9% ammonia.
Sulphate of potash = 7%.
Phosphate of lime (soluble) = 18%.
" " (assimilable) = 4%.

A certain writer says: "I have used the above 'Special Manure,' and have just finished reaping (from a first crop) 260 tons of sugar (net), and over 21,000 gallons of molasses from 82½ acres of canes."

It is important for cane-growers to remember that a good soil for their purpose should contain at least 0·97 per cent. of lime and 0·3 per cent. of magnesia. There is little doubt that the "cane soils" of the West Indies would be greatly improved by the addition of lime and magnesium sulphate.

(*i*) For CARROTS and PARSNIPS the land should be dressed with 12 to 15 tons (per acre) of *rotten* farmyard dung in the autumn.

(*j*) For KOHL RABI from 10 to 12 tons of good farmyard manure per acre. The manure to be followed by 3 or 4 cwts. of blood manure or high quality superphosphate of lime.

(*k*) For PRICKLY COMFREY (*Symphytum asperrimum*) (Fig. 5) a heavy dressing of 30 tons of rotten farmyard manure per acre is required for this excellent forage crop. All kinds of soil suit comfrey, but it appears to thrive best in rich loam.

The plant is, in this country, propagated by dividing

its tuberous roots, and the portions are then planted in the same way as the potato.

The "sets" should be from 16 to 18 inches apart each way (*i.e.*, about 19,300 per acre). The plants, in time,

FIG. 5.—PRICKLY COMFREY (*Symphytum asperrimum*).

completely cover the ground, when the crop may be cut with a scythe in the same manner as clover or sainfoin. Four or five heavy cuttings may be obtained in one season. According to a writer in the *North British*

Agriculturist (May 7th, 1879): "Comfrey produces more weight per acre than any other green crop, having yielded from 80 to 120 tons per acre, according to the soil. . . . The roots may be divided and planted at all seasons of the year, *except in frosty weather.*" In the winter the roots ought to be well dressed with dung or liquid manure.

Comfrey is a perennial plant, so the chief part of the cost of cultivating it is at the time of first "laying a field down" with it.

According to an analysis by the late Dr. Voelcker, comfrey has the following compositions:—

	Leaves.		Stem.	
	In Natural State.	Calculated Dry.	In Natural State.	Calculated Dry.
Water	88·400	—	94·74	—
Albuminoids (Flesh-forming substances)	2·712	23·37	0·69	13·06
Carbohydrates (Heat and Fat producing substances)	6·898	59·49	3·81	72·49
Ash	1·990	17·14	0·76	14·45
	100·000	100·00	100·00	100·00

The farmer must bear in mind that *Prickly Comfrey* is a different plant from the common comfrey (*Symphytum officinale*) which is a native of Great Britain.

To conclude the chapter. We have given all the principal details on the use of farmyard manure for different crops and soils. But "general rules for practice can only be given, and the farmer will have to discover what modifications, if any, are required to suit the

specialities of his own case. Circumstances of soil, locality, and climate bring into operation different causes, and produce different effects; and the student of agriculture [and the farmer ought to be a student] should ever remember that successful practice in one does not ensure like success in another locality. Farming requires the exercise of perpetual observation, and a constant registration of facts and the results of experience."

CHAPTER IV.

ORGANIC MANURES (*continued*).

In this chapter we continue the description of the organic manures which principally supply the soil with nitrogenous substances.

(1) Human Excrements.

According to the late Professor Way, human excrements contain:—

	Organic Nitrogen equal to Ammonia.	Phosphoric Acid.	Potash.
Solid	1·82 per cent.	1·07 per cent.	0·30 per cent.
Dried fæces . . .	7·28 ,, ,,	4·27 ,, ,,	1·19 ,, ,,
Liquid excrements	0·71 ,, ,,	0·06 ,, ,,	0·05 ,, ,,

It is therefore evident that the fertilizing properties of "night-soil" are very low. The *solid* excrements contain about the same percentage of water as ordinary farmyard manure (*i.e.*, nearly three-quarters of its weight consists of water).

Several systems have been invented for the utilization of human excrements. One of these is known as the "earth-closet system." It consists in covering the excreta (solid and liquid) with earth and ashes. By this means the liquid portion of the excrements is absorbed, and the excrements are thoroughly deodorized. There is

only one difficulty in the way of the general utilization of this system, and that is, "it entails the bringing in dry earth to the amount of from 5 to 10 lbs. for each individual daily."

The cultivators of the soil in China and Japan utilize the excrements of man as manure for various crops.

Many of the Chinese tea plantations are treated with this manure.

In Belgium and France the "night-soil" is generally dried with gypsum (sulphate of lime) and other calcareous substances. Gypsum is also useful in promoting the nitrification of the fæcal organic matter. The manure. (after drying) is sold under the name of "Poudrette." It contains about 2·0 per cent. of nitrogen, 1·5 per cent. of potash, and $3\frac{1}{4}$ per cent. of phosphate of lime.

SEWAGE MANURE.—In large towns (Manchester, Liverpool, Birmingham, etc.) various methods are used for the precipitation of sewage. But, whatever method is used, the precipitation is *incomplete*, for the urea and uric acid of the liquid excrements are *not* precipitated, and are consequently lost.

The "A B C" process (which is one of the best known methods for treating town sewage) consists in precipitating the manurial constituents by the addition of clay, alum, charcoal, etc., to the sewage. The dried precipitate constitutes a manure known in the market as "Native Guano."

According to recent analyses of Professor Dewar, F.R.S., and Dr. C. Meymott Tidy, F.C.S., "Native Guano" (obtained by the A B C process) contains on an average 3·8 per cent. of nitrogen, reckoned as ammonia, and 5 per cent. of phosphoric acid, reckoned as tricalcium phosphate (bone phosphate). As there is a sufficiency of organic matter (*i.e.*, carbonaceous), no ammonia is lost by

volatilization if "Native Guano" is kept for several months.

The author is informed that this manure is never sold with a guaranteed analysis, as it is not a manufactured manure, but simply the product obtained from sewage by the company's process.

The composition of the manure varies from time to time, owing to the varying character of the sewage.

The table below gives the results of two *old* analyses of this manure.

"NATIVE GUANO," A B C PROCESS.

Water	7·91	6·12
Organic matter	19·40	22·45
Tricalcium phosphate	2·40	2·81
Lime carbonate	20·93	6·37
Clay and sand	37·66	52·10
Iron oxide and alumina	9·78	6·59
Magnesia and alkalies	2·92	3·56
	101·00	100·00

"Native Guano" is recommended for a large variety of crops. Amongst these are the following:—

For WHEAT, apply from 4 to 8 cwts. per acre in the autumn, and well harrow or drill in with the seed. It is also useful as a top-dressing in the spring.

For ROOT CROPS, apply from 8 to 12 cwts. per acre.

For OATS and BARLEY, from 6 to 10 cwts. per acre are the usual quantities recommended, at the time of sowing.

For GRASS lands, an application of 10 to 15 cwts. is said to be the most beneficial, if applied in the early spring.

For CLOVER, from 8 to 10 cwts. of the manure, applied in the autumn or early spring.

For POTATOES, the quantity of this manure ordinarily used is from 6 to 10 cwts. per acre, applied in the rows, covering with a little soil, or sown broadcast when hoed.

(2) THE MANCHESTER CORPORATION'S MANURE.

This "manure" is composed of the excrements from pail closets; blood, bones, and offal from the city slaughter-houses; fish from the fish markets and fishmongers, etc.

Therefore, this manure is rather a mixture of human excrements and various animal substances than a true sewage manure.

The following analyses represent the composition of this manure:—

	ANALYSTS.		
	Dr. A. P. Aitken.	A. Smetham, F.C.S.	The Corporation's Chemist.
	Per cent.	Per cent.	Per cent.
Organic matter	35·50	35·25	38·66
Containing nitrogen . . .	3·43	3·41	—
Equal to ammonia . . .	4·16	4·14	3·60
Phosphoric acid	—	3·75	—
Equal to tribasis phosphate	7·82	8·20	8·57
Alkaline salts	5·99	6·55	5·08
Containing potash . . .	0·96	0·84	0·90
Lime	—	5·43	—
Equal to sulphate of lime .	2·69	13·19	2·50
Iron oxide and alumina . . .	3·70	—	—
Moisture	17·20	—	—
Silicious matter	22·97	—	—

The "Manchester Manure" has the appearance of fine

mould, and is sold with a guarantee to contain at least 3 to 4 per cent. of ammonia, and $8\frac{1}{2}$ per cent. of phosphates.

The following directions are given as a general guide for farmers using this manure:—

	Quantity per acre.	General remarks.
For wheat	6 to 7 cwts.	
,, grass	6 to 8 ,,	Applied in early spring
,, clover	6 to 8 ,,	,, ,, ,,
,, oats and barley	6 to 7 ,,	At time of sowing
,, roots	10 to 15 ,,	Sown broadcast or drilled
,, legumes	10 ,,	At time of sowing
,, potatoes	10 to 12 ,,	

Perhaps the best method for the utilization of sewage is by the irrigation of the land.

Irrigation should only be practised upon porous and well-drained soils. It is far more economical, and pays better, for sewage farms to be solely utilized for the production of grass and vegetables.

M. Nantier, in the *Annales Agronomiques* (vol. xiv. p. 255), gives the following results obtained from *irrigated* and *non-irrigated* pastures:—

	Irrigated pastures.	Non-irrigated pastures.
	Per hectare.[1]	Per hectare.
Hay (first cut)	5,000 and 6,000 kilograms[1]	1,500 kilograms
,, (second cut)	2,700 and 3,500 kilograms	Nil.

Nantier's experiments were made at the well-known

[1] 1 hectare = 2·47 acres.
1 kilogram = 2·205 lbs.

agricultural station of La Somme in the north of France.

In the suburbs of the French capital, there are several good sewage farms, all of which send their produce (chiefly vegetables) to the Halles Centrales,[1] the largest market in Paris.

(3) Liquid Manure.

"The principal liquid manures produced on a farm are those that run from the manure heaps and the urine of the farmhouse. These should be collected, and used for watering the manure heap; or, if not required for this purpose, might be applied to the land by means of water carts. . . . Liquid manure is rapid in its action, and is largely used on the Continent for light soils.

"It does very well on light sandy soils with a porous subsoil; but its application is a failure on heavy clay soils, making them too cold, etc. On farms composed of heavy clayey soils, the liquid manure should be absorbed by either charcoal or sawdust. It then forms a good manure, lightening the texture of heavy soils, as well as increasing their fertility.

"Liquid manures have proved beneficial in the case of root crops, and for grass, but not for cereals.

"In collecting liquid manures, it is better to preserve them in water-tight tanks—the addition of rain-water lessens their value" ("Treatise on Manures").

(4) Sheep-fold Manure.

This manure is richer in fertilizing constituents than

[1] This market covers an area of 22 acres, and has 1,200 cellars for storage purposes.

ordinary farmyard dung. The droppings are increased in manurial value if the sheep are fed upon oil-cakes in addition to the crop that is eaten off the land.

According to Cameron, the dung of sheep contains 36 per cent. of solid matter containing 0·6 per cent. of nitrogen and over 0·5 per cent. of phosphoric acid. The liquid excrements of sheep contain 0·8 to 1·0 per cent. of potash. These valuable constituents vary according to the food consumed.

Sheep-folding is a very useful means of preparing a light sandy soil for wheat crops.

(5) Blood Manures.

Dried blood forms a valuable fertilizer, supplying nitrogen, potash, and phosphoric acid to the soil.

In its natural state, blood contains from 2·5 to 5 per cent. of nitrogen, and when dried from 6 to 14 per cent. Blood decomposes more rapidly than farmyard manure. The organic nitrogen which it contains is soon converted into ammonia and soluble compounds.

The ashes of blood contain the following percentages of phosphoric acid and alkalies (potash and soda):—

	Sheep.	Calf.	Ox.	Pig.	Dog.
Phosphoric acid	14·80	20·14	14·01	36·5	36·82
Alkalies	55·79	66·57	59·97	49·8	55·24

Blood is sent into the market in various forms. Amongst these are the following:—

(*a*) In the form of a red powder.
(*b*) Raw "clotted" blood (in a liver-like state).
(*c*) "Acided" clotted blood.
(*d*) Flesh and blood manure.

In the *powdery* condition, according to certain analyses, blood manure contains nitrogen equal to 14 or 15 per cent. of ammonia. In this condition (*i.e.*, as a powder) it makes a good manure for root crops. Blood in the form of a compost makes an excellent top-dressing for grass-land, especially when applied in the middle of March.

The *raw clotted blood* contains nitrogen equal to 6 or 7 per cent. of ammonia. It is in a liver-like state, but is cut into pieces about an inch square before it is sent into the market.

This form of blood is useful for mixing with poor superphosphates, and is often ground up with mineral superphosphates (by the manure manufacturer), to give to the manure a certain percentage of nitrogen.

The "*acided clotted blood*" is blood treated with oil of vitriol, which prevents its decomposition. It is in the form of small semi-dry lumps, and contains about 7 per cent. of nitrogen reckoned as ammonia.

The farmer can easily coagulate blood by adding a certain quantity of gypsum (sulphate of lime). The addition of gypsum to blood causes a more rapid decomposition in the soil; *i.e.*, gypsum promotes nitrification, or the conversion of *insoluble* nitrogenous plant-foods into *soluble* ones (nitrates). Blood manures containing gypsum are quicker in their action than when this mineral substance is not present.

The question may be asked,—What crops are most benefited by blood manures? In the words of the late Professor Way:—

"The crops which dried blood will benefit are wheat, hops, grass, turnips; indeed, it will not fail to do good to any kind of vegetation."

According to M. Samek (*Biedermann's Centralblatt für*

Agricultur-chemie, 1888, p. 527), the best nitrogenous manure for *clover* growing on *sandy loams* is blood-meal[1] mixed with superphosphate of lime.

For turnips 48 bushels per acre (or 16 bushels with good farmyard manure), and 20 to 30 bushels have been used as a top-dressing for wheat, with good results.

As shown by a large number of experimental trials made in different parts of the world, blood manures form excellent dressings for sandy and loamy soils.

(6) Shoddy Manures.

Woollen refuse and shoddy are essentially nitrogenous manures. They contain from 5 to 10 per cent. of organic nitrogen, and have proved useful for hops.

(7) Sawdust.

The chief objection to the use of sawdust as a manure is its slow decomposition. A manure to be of value should act quickly. Nevertheless, sawdust is useful as an absorbent; and if laid about the lower parts of a yard, or even round the entrances of cowsheds, it will retain much fertilizing matter, which would otherwise be lost. The sawdust now being impregnated with the excrements of the farmyard decomposes far more rapidly than when in the raw state.

In this state it forms a *tolerably* good manure for turnips.

(8) Tanners' Bark.

Spent bark is a difficult substance to work up into

[1] Blood dried and then ground to powder.

manure. It however decomposes with lime, and a compost is made of the following materials :—

Spent bark	30 bushels.
Lime	15 ,,
Bones (ground)	8 ,,
Ammoniacal or gas liquor .	15 gallons.

This mixture must be allowed to ferment for about a month, when it will be ready for use.

(9) Oil-cake Manures.

The various oil-cakes contain from 4 to 7 per cent. of nitrogen reckoned as ammonia, and from 3 to 5 per cent. of phosphates.

Oil-cake dust forms an excellent constituent of manures for spring wheat, potatoes, turnips, and mangel-wurzels. The quantity of rape-cake for cereals growing on strong clayey soils is from 5 to 6 cwts. per acre.

It can also be drilled in with winter or spring wheat with advantage.

The best drills, in our opinion, for this and similar purposes, are those made by Mr. James Coultas, of Grantham, Lincolnshire (Fig. 6).

As a general rule, oil-cakes are far too valuable *foods* (for fattening cattle, etc.) to allow them to be used, to any great extent, as manures.

(10) Green Manures.

These manures supply the land with carbonaceous matter and nitrogen.

"Green manuring consists in allowing a green crop (like turnips, mustard, rape, etc.) to grow until *almost* mature, and then ploughing it into the land."

Green manuring enriches the *surface* soil in two ways:—

(*a*) By the organic constituents which the crop derived from the atmosphere.

(*b*) The roots of the crop have brought up mineral and nitrogenous substances from the subsoil, which are thus

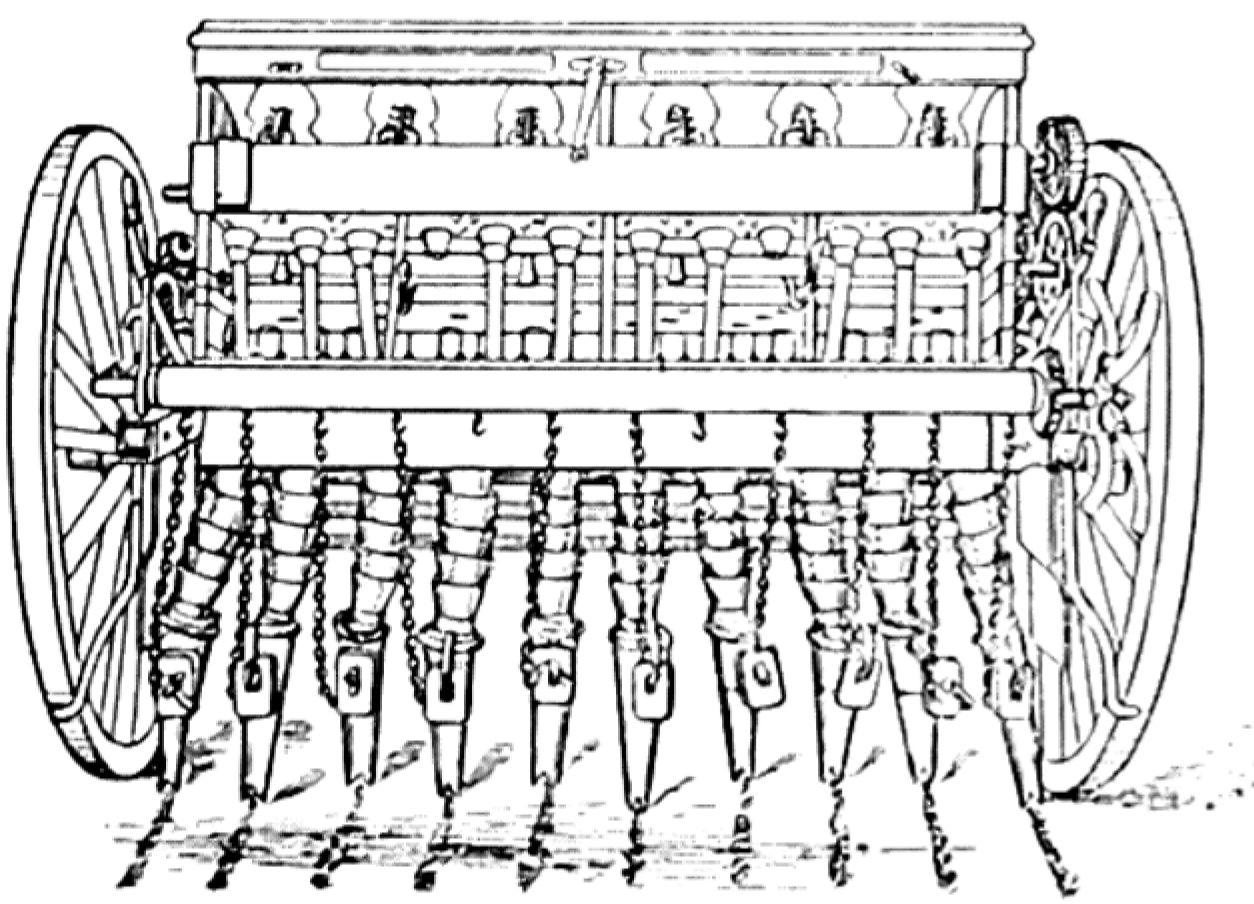

FIG. 6.—THE "GENERAL PURPOSE" DRILL.

This drill is capable of drilling every description of seed, with or without manure.

returned to the land. By this means the fertility of the surface soil is greatly increased.

"It is stated that green manures produce 'the greatest effect on light and sandy soils in dry climates,' but they are also of great service on heavy clays."

Green manuring effects various chemical reactions in the soil. The carbonic acid gas produced during the decomposition of green manures disintegrates the soil,

converting some of the insoluble compounds into soluble plant-foods.

Green manures, like farmyard manure, warm the land and add to its power of retaining ammonia and moisture; hence the reason that this method of manuring is so valuable for light porous soils.

SEAWEEDS must also come under the head of "green manures." They supply chiefly nitrogen and potash to a soil. The potash (in the ashes) varies from 4 to 20 per cent., according to the species. *Fucus digitatus* contains 20·66 per cent. of potash, while *Fucus serratus* contains only 3·98 per cent.

Seaweeds decompose very rapidly in the land, forming excellent manures for potatoes, turnips, and mangel-wurzels.

For those farms near the sea-coasts, the common *Fucus* should be used as a potasso-nitrogenous manure, at the rate of 20 to 30 tons per acre.

CHAPTER V.

ARTIFICIAL MANURES.

"ARTIFICIAL manures are now in great request amongst practical farmers; they are valuable as applying in a concentrated and available form the mineral constituents to land which has become unproductive through long cultivation. . . . Artificial manures owe much of their value to the peculiarities of the soil to which they are applied, 'each soil being endowed with its own peculiar capacity for receiving and retaining the fertilizing matter supplied to it.' Hence the necessity for becoming acquainted with *the nature of a soil* before deciding on the kind of artificial manure to be applied to it."

Artificial manures act in *various* ways.

(*a*) As direct plant-foods, supplying the crops with phosphoric acid, lime, potash, nitrogen, etc.; thereby making good the deficiencies of the soil.

(*b*) Most artificial manures act as indirect plant-foods, by causing various chemical changes in the inert constituents of the soil, by this means converting the inert substances into soluble or available plant-foods.

(*c*) Artificial manures improve the texture of the soil.

Before artificial manures are applied, it is essential that the farmer should have a good knowledge of the physical and chemical condition of the soil, and the requirements of the crop to be grown on such soil. Artificial manures are not equally efficient on all classes of soils; usually they are more so on clayey than on sandy soils.

Most artificial manures are wholly or partially soluble in rain-water, and therefore can be immediately absorbed by the roots of plants. As a rule, they are quick-acting manures, not necessarily stimulants, but readily available plant-foods.

Artificial manures like nitrate of soda, ammonium sulphate, iron sulphate, etc. (*i.e.*, very soluble manures), should be applied only as top-dressings when the crops are above ground.

It is better for the farmer to apply the usual quantities of these very soluble manures in two or three dressings, rather than in one. The extra labour necessary for *fractional top-dressings* is paid for by the increased yield. By using fractional top-dressings, the farmer feeds his crops, step by step, and produces perfectly healthy crops, less prone to disease than when the dressing of artificials is given in one application.

Artificial manures are greatly affected by the weather. Very wet and very dry seasons are alike unfavourable for the proper action of artificial manures. "In the one case, portions of their most valuable constituents are washed into the subsoils and drains, and in the other they remain in an inactive condition."

It is not economical to apply soluble manures in *very wet* weather, for there is a great loss, although the most suitable time for top-dressing is in *damp* weather. Most artificial manures ought to be in a finely divided condition, so that the rains may distribute them equally and in all directions in the soil.

Manures (like bones, bone-dust, shoddy, etc.) whose constituents are in an *insoluble* form, should be applied in the autumn. When applied in the autumn, they have time to become "weathered" or rendered partially or

wholly soluble before they are required for the active growth of the crop in the following spring.

As a general rule, manures which are only *partially* soluble (like guano, superphosphates, etc.) should be applied early in the spring.

"When drill husbandry is employed in the sowing of grain crops, the manure will be most effectually applied immediately previous to horse-hoeing, which will have the combined effect of destroying the weeds and thoroughly mixing the manure with the soil; of course when applied at seed-time, it ought to be harrowed in at once with the crop, for there is practically a considerably greater increase from guano thus applied, than when top-dressed at a more advanced stage."

"For *root* crops artificial manures are best applied at seed-time. Should the land have received a winter manuring of dung, the artificial manure may be sown broadcast, harrowed in, and drilled up ready for sowing; if not, and the dung be applied also at the seed-time, it may then be sown broadcast over the top of the drills on the top of the dung, and thus be split in along with it. Bone-dust or superphosphate may be drilled in along with the seed, by a combined manure and seed drill [Fig. 7]; but guano, rape-cake, and all nitrogenous and alkaline manures are recommended to be distributed broadcast, and well mixed with the soil, inasmuch as nitrogenous manures are found to exercise a prejudicial influence on *the delicate seed and young plant*, and therefore ought never to be applied near to it, especially in a *dry* season" (Wilson).

We will now describe the various "artificials" used in practical farming, beginning with bones.

(1) Raw Bones.

The author has stated elsewhere that "although bones come from the *animal* kingdom, it is better for many reasons to include them under the head of artificial manures. One of these reasons is that they are allied to the phosphatic guano, and receive similar treatment in

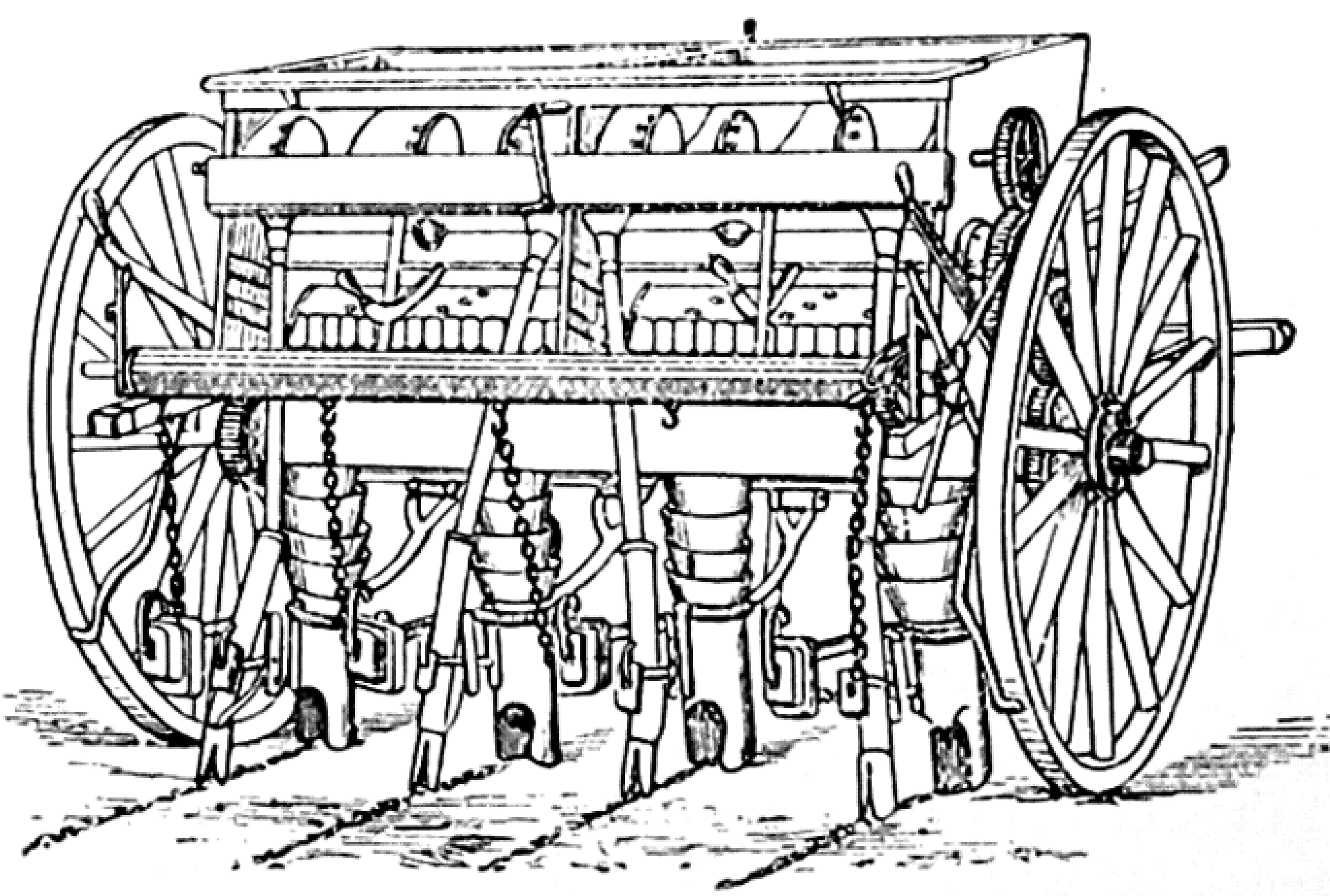

Fig. 7.—Manure and Seed Drill.

The above drill is constructed for drilling turnip, mangel-wurzel, and other roots (*i.e.*, their seeds) with manure.

rendering their phosphates *soluble*, as in the preparation of superphosphates."

Bones are principally phosphatic manures, although they contain small percentages of organic nitrogen. Raw bones contain about 4·2 per cent. of nitrogen, while boiled and steamed bones contain from 1·2 to a little over 3 per cent.

Bones constitute a permanent agricultural improvement. Many worn-out farms, requiring phosphates, have been completely renovated by the application of bone manures.

According to the author's observations, on *highly* cultivated lands, bones ($\frac{1}{2}$-inch) take on an average seven years for their complete disintegration in the soil. Therefore they form, to a certain extent, a permanent supply of phosphoric acid. Although the phosphoric acid present in bones is in an *insoluble* condition, a portion of the lime with which it is combined is continually uniting with various acids which are constantly being formed in soils; and by this means the phosphoric acid becomes soluble. For instance, *nitric acid* (a product of nitrification) and *carbonic acid* (formed by the decomposition [oxidation] of organic carbon) extract one or maybe two equivalents of lime from the insoluble tri-lime phosphate or bone phosphate; and thereby are converted into bi- or mono-lime phosphates, both of which are easily taken up by the rootlets of plants.

The reader who is acquainted with chemistry will readily understand the so-called "weathering" of bones by referring to the following equations:—

$$(\alpha)\ \underset{\text{[Insoluble]}}{Ca_3P_2O_8} + 2HNO_3 = \underset{\text{[Soluble in weak acids]}}{Ca_2H_2P_2O_8} + Ca(NO_3)_2.$$

$$(\beta)\ \underset{\text{[Insoluble]}}{Ca_3P_2O_8} + 4HNO_3 = \underset{\text{[Very soluble]}}{CaH_4P_2O_8} + 2Ca(NO_3)_2.$$

$$(\gamma)\ \underset{\text{[Insoluble]}}{Ca_3P_2O_8} + CO_2 + H_2O = \underset{\text{[Soluble in weak acids]}}{Ca_2H_2P_2O_8} + CaCO_3.$$

$$(\delta)\ \underset{\text{[Insoluble]}}{Ca_3P_2O_8} + 2CO_2 + 2H_2O = \underset{\text{[Very soluble]}}{CaH_4P_2O_8} + 2CaCO_3.$$

Bones, in the crushed condition, have proved (in various

parts of the country) valuable manures for turnip crops. Also "the worn-out pastures of Cheshire have had a new lease of fertility given to them by the use of this manure."

Good quality bones should contain 45 per cent. of phosphate of lime and 4 per cent. of nitrogen.

The following analyses give the composition of bones:—

	Analysts.			
	Mr. Fairley.	Dr. Voelcker.	Dr. A. B. Griffiths.	Dr. Voelcker.
	Good quality.	Adulterated Bone-meal.	Good quality.	Adulterated Bone-meal.
Moisture	8·38	14·35	7·91	23·41
Organic matter . .	31·12	26·80	31·60	23·69
(Containing nitrogen)	(4·06)	(2·07)	(4·12)	(1·22)
Lime phosphate .	49·43	24·06	48·91	1·66
Carbonate of lime .	9·56	} 33·19	6·41	—
Sulphate of lime .	Trace		—	35·15
Alkaline salts . .	—		4·02	—
Sand	1·51	1·60	1·12	11·45
Iron oxide and alumina . . .	—	—	—	4·64
	100·00	100·00	100·00	100·00

Concerning the last of the above analyses, the late Dr. Voelcker, F.R.S., reported on the manure as follows:— "The manure sent by you is not bone-dust at all, but a refuse manure of but little value. You say you purchased it at £6 15*s.* per ton delivered. I would not give more than 25*s.* per ton for such a manure" (*Journ. Royal Agric. Soc.*, April, 1885).

Bones are reduced, in bone-grinding works, to "half-inch," "quarter-inch," and bone-meal.

Half-inch bones and quarter-inch bones are used for pastures, turnips, etc. They are slow in action.

Bone-meal or bone-dust has a quicker action in the soil than either half or quarter-inch bones. Bones reduced to a finely divided state by grinding are often adulterated with sulphate of lime. Dr. Voelcker's analysis (in the previous table) shows that a sample of bone-meal was adulterated with this substance (gypsum) to the extent of 35 per cent., *i.e.*, more than one-third of its weight was composed of this cheap substance. Bone-meal is a valuable manure for turnips, and is best applied with the seed, using the water-drill.[1]

Bone manures, as a rule, are better adapted for light soils than heavy clay land.

"Bone-meal is used as a top-dressing for pasture land at the rate of 9 to 14 cwts. per acre."

Bones were the earliest phosphatic manures used in this country; and "our first source of phosphoric acid for the manufacture" of superphosphates. In the early days of the superphosphate industry, even earlier, England imported large quantities of bones for agricultural purposes. It is stated that in 1822 Germany exported to England no less than 33,000 tons of bones.

After Liebig had made his famous discovery of preparing *soluble* phosphates by vitriolizing bones, he saw a source of wealth to his own country gradually passing into the hands of English agriculturists. On this he wrote as follows:—

"England is robbing all other countries of the con-

[1] The water-drill enables the agriculturist to sow turnips, etc., with manure suspended in water. The water can be applied at the rate of from 200 to 600 gallons per acre.

ditions of their fertility. Already, in her eagerness for *bones*, she has turned up the battlefields of Leipzig, of Waterloo, and of the Crimea; already from the catacombs of Sicily she has carried away the skeletons of many successive generations. Annually she removes from the shores of other countries to her own, the manurial equivalent of three millions and a half of men, whom she takes from us the means of supporting, and squanders down her sewers to the sea. Like a vampire she hangs upon the neck of Europe, nay, of the entire world, and sucks the heart-blood from nations, without a thought of justice towards them, without a shadow of lasting advantage for herself."

England imports annually nearly 100,000 tons of bones from foreign countries. This represents a money value of over half a million pounds sterling.

"Our supply of bones from *home* collections is no doubt increasing, and may now be estimated at about 60,000 tons per annum, of which 22,000 tons are collected in and round London."

(2) Fermented Bones.

Fermented bones are more valuable as manure than *raw* bones. By fermentation many of their insoluble constituents are rendered soluble, and thereby become available plant-foods. Fermented bones do not effect a *permanent* agricultural improvement, for their action in the soil is much quicker than that of raw bones; hence they are invaluable for quick returns in the form of crops.

Fermented bones are easily prepared by mixing raw bones with clay and watering the mixture with urine or stable runnings. The mixture should be protected from

rain by a covering of damp clay, but otherwise exposed to the atmosphere.

Fermented bones contain about 49 per cent. of phosphates (partly soluble), and about 29 per cent. of organic matter containing 4·2 per cent. of ammonia. When applied at the rate of 30 to 40 bushels per acre on pasture lands, fermented bones have often proved excellent top-dressings.

For turnip crops the land should receive about 25 bushels per acre.

(3) Steamed and Boiled Bones.

By boiling or steaming bones (operations which are carried out in most bone works) the gelatine is extracted and used for the manufacture of glue.

The residue, after extracting the gelatine, is known as "boiled" or "steamed" bones.

Bones, after the extraction of the gelatine, contain less organic matter, and therefore contain less nitrogen, than before boiling. By extraction of organic matter the percentage of phosphate of lime is increased. The following table shows the percentages of nitrogen and phosphate of lime contained in both boiled and raw bones:—

	Raw Bones.	Boiled Bones.
Nitrogen	4·12	1·76
Phosphate of lime	48·91	60·19

The phosphate of lime in "boiled" or "steamed" bones is more soluble than in raw bones. Genuine "boiled" or "steamed" bones should contain fully 60

per cent. of phosphate of lime, and nitrogen equal to about 2 per cent. of ammonia.

Steamed bone-meal takes from ten to twelve months to decompose in the soil. Hence "steamed" bones do not form a permanent agricultural improvement.

(4) Bone-ash.

This manure is chiefly imported from South America. In 1887, South America exported 17,386 tons of bone-ash and bones to Great Britain. Bone-ash, or the residue from burnt bones, is largely used by manure manufacturers.

Bone-ash contains from 60 to 85 per cent. of phosphate of lime, and about 1 per cent. of alkaline salts.

Bone-ash is essentially a phosphatic manure. It supplies the soil with phosphates only, for it contains no nitrogen, this ingredient having been lost in the burning.

Bone-ash is chiefly used in the manufacture of "bone-ash superphosphate," a manure which is different from "dissolved bones," or "bone superphosphate," inasmuch as "dissolved bones" contain *nitrogen*, while "bone-ash superphosphate" does not contain this valuable plant-food.

(5) Bone Superphosphate.

Bone superphosphate (dissolved bones) is prepared by treating bones with sulphuric acid (oil of vitriol).

The chemical reaction of oil of vitriol upon bones is, in its simplest form, expressed by the following equation:—

$$\underset{\text{Bone phosphate.}}{Ca_3P_2O_8} + \underset{\text{Oil of vitriol.}}{2H_2SO_4} = \underset{\text{Gypsum.}}{2CaSO_4} + \underset{\substack{\text{Bone or lime}\\ \text{superphosphate.}}}{CaH_4P_2O_8}.$$

By this reaction the *insoluble* bone phosphate is con-

verted into a *soluble* "superphosphate." This is done by substituting four equivalents of hydrogen for two equivalents of calcium in *tri*calcium or bone phosphate; leaving the whole of the valuable phosphoric acid in combination with one equivalent of calcium.

The *mono*calcium phosphate (superphosphate) is soluble in water, and therefore a readily available plant-food.

Bones for the preparation of *bone* superphosphate are never reduced to a powder. They are merely broken into quarter or half-inch bones. "The object of not grinding the bones in the preparation of superphosphates is that the bones shall appear in the manufactured article. This is done solely to suit the whim of the agriculturist, who can thus see for himself that bones have been used in the preparation of the manure. This practice is detrimental, for the calcium phosphate in the bones is only partially acted on by the sulphuric acid—and superphosphates from such a source are apt to 'retrograde,' or diminish in *soluble* phosphate by keeping" ("Treatise on Manures").

Genuine bone superphosphates contain from 11 to 19 per cent. of monocalcium phosphate, from 8 to 15 per cent. of tricalcium phosphate, and from 0·8 to 1·9 per cent. of nitrogen.

Dissolved bones are beneficial for most crops, and supply the land with soluble phosphoric acid and a small quantity of nitrogen.

For turnips and mangel-wurzels, bone superphosphate should be applied at the rate of 4 to 6 cwts. per acre. For pasture land, 5 cwts. per acre should be applied in the autumn or early spring.

Bone superphosphate derived from previously steamed or boiled bones contains far less nitrogen, and consequently is a poorer manure, than genuine dissolved bones.

(6) Bone-ash Superphosphate.

Bone-ash superphosphate is prepared from the imported *bone-ashes* of South America. Bone-ash contains little or no nitrogen, and in this respect differs from bones. The superphosphate it yields contains a smaller percentage of nitrogen than genuine bone superphosphate.

The average amount of nitrogen in dissolved bone-ash is 0·2 per cent.

For mangel-wurzels dissolved bone-ash should be applied

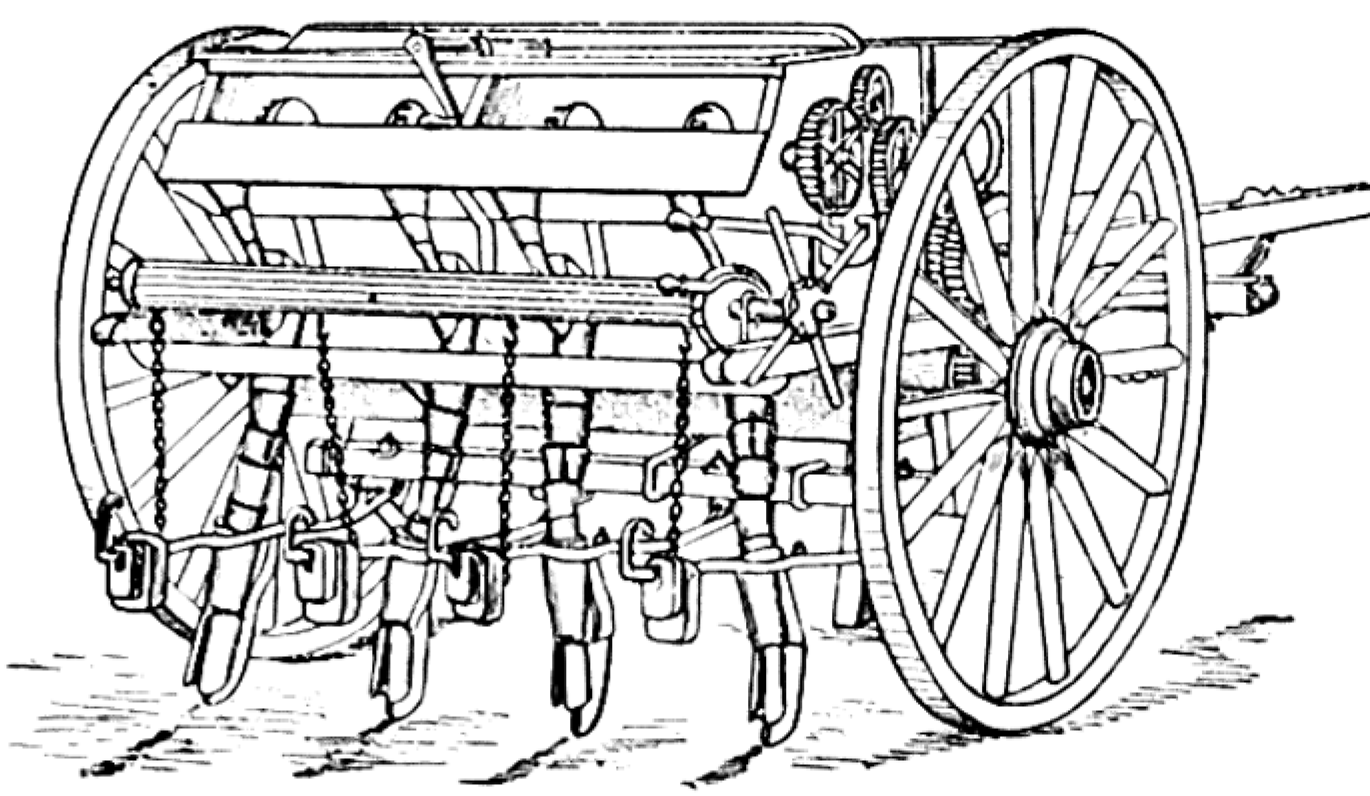

Fig. 8.—Water or Liquid Manure Drill.

at the rate of 5 cwts. per acre, and for turnips 4 cwts. per acre; this forms a good dressing. "Dissolved bone-ash should be in a fine, dry, powdery condition, and when well made is specially suitable for use with the water-drill" (Fig. 8).

"Dissolved bones and dissolved bone-ash are of special importance on cold clayey and stiff calcareous or damp soils. These manures applied to cereals, roots, or grass land promote the early maturity of each crop."

(7) Mineral Superphosphates.

These superphosphates (like bone superphosphates) are prepared by the action of oil of vitriol on mineral phosphates, coprolites, and guanos.

The percentages of tricalcium phosphate and nitrogen which they contain vary considerably.

The best mineral phosphate found in the British Isles is the Cambridge coprolite (with about 56 per cent. of tricalcium phosphate).

The Somme phosphate (of the north of France) contains from 50 to 80 per cent. of tricalcium phosphate. The Belgian phosphate contains from 45 to 60 per cent. of tricalcium phosphate.

All these phosphates and many others are used in this country for the manufacture of superphosphate of lime.

"The object gained in the manufacture of superphosphates is to render the phosphoric acid in a *soluble* condition, so that when it is applied to the land it can be immediately taken up by the living plant." Soluble phosphates *readily* distribute themselves in the land, while insoluble or raw phosphates take a considerable time for the completion of this action.

The next table gives the composition of a good and bad mineral superphosphate :—

	Good.	Bad.
Moisture	20·53	14·40
Organic matter, etc.	14·76	8·93
Monocalcium phosphate	10·31	3·60
(= Tricalcium phosphate)	(16·09)	(5·61)
Insoluble phosphate	17·72	6·83
Calcium sulphate	28·39	44·23
Alkaline salts	1·56	2·51
Insoluble matters	6·73	19·50
	100·00	100·00

Messrs. Lawes' superphosphate of lime (which is made from the best quality of raw materials) contains from 26 to 28 per cent. of soluble phosphates.

Superphosphates, as already stated, are good manures for turnips and root crops generally. For potatoes they should be applied at the rate of 4 to 6 cwts. per acre; "but they must be accompanied with potash salts if the soil is deficient in that ingredient."

From 3 to 4 cwts. of superphosphates as a top-dressing cause the early maturity of barley.

Oats growing in the Fens are greatly benefited by top-dressings of superphosphates, especially if applied in the spring.

(8) Dissolved Peruvian Guano.

This manure is the result of the action of oil of vitriol upon Peruvian guano. The acid renders the tricalcium phosphate and guanine (a nitrogenous substance containing 46·3 per cent. of nitrogen) soluble, and the ammonia fixed (non-volatile).

The best *Dissolved Peruvian Guano* is that made at the Anglo-Continental (Ohlendorff's) Guano Works.

Messrs. Ohlendorff & Co. were the first manure manufacturers who treated genuine Peruvian guano with sulphuric acid; and so rendered the phosphoric acid and nitrogen available plant-foods.

The present company which succeeded the old business firm of Ohlendorff has extensive factories at Hamburg, Antwerp, Emmerich-on-Rhine, as well as in London.

"The London factory covers eight acres of land, and is admirably situated on the Thames." About 300 labourers are employed, besides a number of women who sew bags, etc. The weekly out-put from these works is more than

1,000 tons of dissolved Peruvian guano and other manufactured manures.

The following table gives the composition of "Ohlendorff's" *Dissolved Peruvian Guano.* The analysis is by Mr. H. B. Shepherd, F.C.S.:—

Moisture (loss at 100°C.)	8·55
Organic matter + water of combination	41·64
(Containing nitrogen = 6·76 = 8·21 per cent. ammonia)	
Soluble phosphate of lime	13·18
(Equal to 20·64 per cent. tricalcium phosphate made soluble)	
Tricalcium phosphate (insoluble)	4·02
Sulphate of lime, alkaline salts, and magnesia . . .	27·91
(Containing 2·24 per cent. potash = 4·14 per cent. sulphate of potash)	
Insoluble matter	4·70
	100·00

The late Dr. A. Voelcker, F.R.S., reported that Ohlendorff's *Dissolved Peruvian Guano* was the "most powerful, intrinsically valuable, and best prepared compound fertilizer" which had ever been brought under his notice.

Dr. A. Stöckhardt (the German agricultural authority) states that "*dissolved Peruvian guano* contains large quantities of nitrogen and phosphoric acid; like the raw guano, it is a concentrated manure. In 100 lbs. of this manure there are 7 lbs. of nitrogen and 10 lbs. of phosphoric acid, soluble in water, *i.e.*, about as much *nitrogen* as is contained in 2 tons of half-rotten stable dung, and as much phosphoric acid as is contained in 3 tons of dung. In consequence of the soluble state of the two principal elements, 100 lbs. of *dissolved* Peruvian guano have, in the first year, the same effect as 4,000 to 5,000 lbs. of stable dung."

Ohlendorff's dissolved guano is a dry powdery manure,

and always of an uniform composition. It "neither clogs the drill when sown by machine, nor flies off in dust when sown broadcast by hand."

It is an excellent manure for cereals, roots, leguminous and other crops.

The following table is given as a general guide to the farmer using this manure for various crops:—

APPLICATION OF DISSOLVED PERUVIAN GUANO.

Crops.	Quantity of Manure per acre.	Remarks.
Winter wheat .	3 to 4 cwts.	Sown broadcast and lightly harrowed in before the seed is sown.
Spring wheat .	3 to 4 cwts.	The manure should be mixed with 1 cwt. of salt before drilling in the seed.
Potatoes . . .	4 to 5 cwts.	Applied when potatoes are drilled if land has been previously dressed with dung. Without dung the dressing of guano should be from 6 to 8 cwts.
Pasture grasses	3 to 4 cwts.	Best applied in autumn.
Turnips . . .	3 to 4 cwts.	2 cwts. of mineral superphosphates should be mixed with the guano, both for light and heavy soils.
Mangel-wurzels	4 to 6 cwts.	Mixed with 2 cwts. of common salt.
Clover . . .	4 to 5 cwts.	Applied as a top-dressing in the winter or early spring.
Barley and oats	3 to 4 cwts.	Mixed with 2 cwts. of salt. The manure to be sown broadcast before seeding.
Flax . . .	4 cwts.	Sown broadcast and harrowed in before seeding.

The manurial action of dissolved guano is quicker than raw guano.

From a large number of experiments performed in different parts of the world, and therefore under various

climatic conditions, it appears that dissolved Peruvian guanos are particularly suited for strong clayey lands, rather than those of a light sandy nature.

(9) Retrograde Phosphates.

"It has been known for several years that in some superphosphates the percentage of soluble phosphates (soluble in water) gradually decreases. Thus a 20 per cent. superphosphate will be decreased to 18 or 16 per cent., or even less, in the space of a few months" ("Treatise on Manures").

The cause of this backward change is most likely produced by the *insoluble* phosphate (left in the manure to dry it) reacting upon the *soluble* phosphate, and thereby producing "retrograde," "reduced," or bicalcium phosphate.

The reaction is represented by the following chemical equation:—

$$\underset{\substack{\text{Tricalcium}\\\text{phosphate.}}}{Ca_3P_2O_8} + \underset{\substack{\text{Monocalcium}\\\text{phosphate}\\(\textit{superphosphate}).}}{CaH_4P_2O_8} = \underset{\substack{\text{Bicalcium phosphate}\\\text{(retrograde phosphate).}}}{2Ca_2H_2P_2O_8.}$$

"The bicalcium phosphate formed is not so soluble in water (say rain-water) as superphosphate, but far more soluble than bone-earth or raw coprolites."

If mineral phosphates containing a comparatively large percentage of iron oxide and alumina are used in the preparation of superphosphates, the product is liable to "retrograde."

Some agriculturists and chemists consider "reduced" or "retrograde" phosphates of as great, if not of greater value than superphosphates.

Retrograde phosphates are not so easily washed out of

the land by drainage as the very soluble superphosphates.

Retrograde phosphate has a far less diffusive power in soils than superphosphate.

Farmers are becoming more and more aware of the importance of adding phosphatic manures to all cultivated soils. "M. Grandeau (the French agricultural authority) recently estimated that one year's crop in France represents 298,200 tons of phosphoric acid, of which only 151,200 tons were recovered from the stable dung, thus leaving a deficit of 147,000 tons, equal to over one million tons of superphosphate, to be made good by other means." "M. Grandeau also estimated that the entire number of farm animals in France in 1882, representing a live weight of 6,240,430 tons, had accumulated from their food 193,453 tons of mineral matter containing 76,820 tons of phosphoric acid."

"These figures give some idea of the enormous quantities of phosphoric acid required to restore to the soil what is continually being carried away by the crops sold off the farm. Our forefathers in some way already recognised the necessity, by resorting to the use of auxiliary manures; they not only used rich marl for their exhausted fields, but also applied large quantities of bone-meal" (H. Voss).

CHAPTER VI.

ARTIFICIAL MANURES (*continued*).

In the last chapter we considered the manures derived from bones. The present one continues the description, properties, and use of other phosphatic manures, such as the various guanos, coprolites, and mineral phosphates. But before proceeding to describe the properties and uses of guanos, we offer a few remarks on the subject of

DRILLING *versus* HAND-SOWING.

"Drills are now in universal use in England, and are rapidly becoming so in Scotland. The Scotch and north of England farmers have, however, adhered with great pertinacity to the older system of hand-sowing; and as this system is still recognised as useful under certain circumstances by all farmers, it will be interesting to inquire into the relative merits of hand-sowing or broadcasting *versus* sowing by the drill.

"In the case of all root or fallow crops,—*i.e.*, crops which take the place of the old bare fallow, once universally used as a means of cleaning and renovating land,—the advantages of the drill are perfectly clear. A 'fallow' is not effective unless it leaves the land both rich and clean; and when a fallowing or cleaning crop is sown, both objects must be kept steadily in view. The first is accomplished by *liberal manuring* and feeding the crop

upon the land; the second must be secured by cleaning processes before sowing and subsequent interculture. This last requirement involves sowing in rows and the consequent employment of a drill. In the sowing of cereal crops, much may be said in favour of broadcasting. (1) Supposing the land to be clean (free from weed), broadcasting ensures a very equal distribution of seed, each plant being (supposing a perfect system of broadcast sowing) equidistant from its neighbours. (2) It is a much more rapid and cheaper method of sowing, one man being able to sow fifteen acres per day. (3) When the furrow is well laid for the purpose, *i.e.*, presents a good 'seam' for the reception of the seed, or when the ribbing plough is used, broadcasting is as effective as drilling. (4) Upon wet and heavy soils the trampling of horses and the passage over the ground of a heavy implement are avoided; on the other hand, while drilling gives the plants a larger amount of room between the rows, they are crowded in the rows. It is slower and more expensive than broadcasting. It acts injuriously upon wet, stiff clays.

"To all these objections the important fact may be urged, that drilling (both seeds and manures) has triumphed over broadcasting, and has thus proved its excellence. Drilling also possesses the following substantial merits. It ensures the depositing of the seed at a uniform depth; allows of horse and hand-hoeing (interculture), while a saving of seed is effected.

"It is difficult to see how wheat could be sown except with the drill in the south of England, where the general system is to sow upon a surface pressed firm and flat by the Crosskill or Cambridge roll" (Wrightson on "Agricultural Machinery").

There is little doubt that drilling manures or seeds is, in most cases, superior to hand-sowing.

GUANOS.

Guanos are divided into two classes: (α) The nitrogenous guanos, (β) the non-nitrogenous.

The following table furnishes a list of the principal guanos of each class:—

	Nitrogenous Guanos.	Non-nitrogenous Guanos.	
Peruvian guanos	Punta de Lobos	Aves	West Indies
	Pabillon de Pica	Mona	
	Huanillos and Independencia Bay	Tortola	
	Chincha Islands	Baker	Pacific Ocean Islands
	Guañape Island	Jarvis	
	Macabi	Starbuck	
	Ballestas Islands	Enderley	
	Angamos Island	Maldon	
	Ichaboe Islands	Howland	
	Patagonia	Lacepede	
	Falkland Islands	Flint	
	Cape Town (South Africa)	Browse	
	Australia	Sidney	
	Texas ("Bats' Guano")	Phœnix	
		Huon	
		Arbrohlos	
		Mejillones (Bolivia)	
		Kooria Mooria (Arabia)	

Guanos consist of the consolidated excrements of sea-birds. The nitrogenous guanos are only found to any great extent in the "rainless" districts of the world.

Little rain falls west of the Andes; hence the islands on the west coast of Peru and Chili contain large deposits of *nitrogenous* guanos.

In less favoured situations (as in the islands of the

Pacific Ocean) the nitrogenous substances are being continually washed out of the guanos by rain. The residue constitutes the ordinary *non*-nitrogenous guano.

Alexander von Humboldt was the first traveller who gave an account of the Peruvian guano deposits. But nearly half a century elapsed before this knowledge was turned to practical use.

Guano was introduced into England by the Earl of Derby, in 1841. During that year, 1,733 tons of guano were imported into England; while at the present time we use no less than 140,000 tons annually of this important fertilizer.

The annual consumption of Peruvian guano may be divided amongst the various countries as follows:—

Great Britain and Ireland . . .	140,000 tons
France	100,000 ,,
Belgium	70,000 ,,
Germany	60,000 ,,
Other European countries . . .	50,000 ,,
United States of America . . .	35,000 ,,
Mauritius	20,000 ,,
West Indies	15,000 ,,

It will be noticed from the above list that Great Britain and Ireland consume four times as much guano as the States of America. The reason of this is obvious, the soils of this country having been long drained of their natural fertility.

"The *virgin* soils of Britain and France have long passed away, while in some countries—as, for instance, in the United States of America—there are 12,000,000 acres of uncultivated land (with virgin soils) in the State of New York alone, of which 5,000,000 are covered with forests. These soils of America are ready to grow any

farm seed and yield a luxuriant crop. Why will these virgin soils yield full crops without any addition of artificial or natural manures? Because they contain all the mineral, carbonaceous, and nitrogenous principles required for plants generally. They have not been cultivated for centuries, like the soils of the Old World" ("Treatise on Manures").

All cultivated lands have a tendency to become barren, owing to the constant draining of their fertilizing principles by the growth of crops, and the demands of an ever-increasing population.

In France "one year's crop represents 298,200 tons of phosphoric acid, of which only 151,200 tons are recovered in farmyard manure." It is the same in Britain. Hence it becomes imperative that British farmers should replace in the soil all the substances of vital importance for plant nutrition and growth.

Genuine Peruvian guano is the most important of all the artificial manures. One ton of Peruvian guano was estimated by Nesbit to be equal in fertilizing properties to over 33 tons of good farmyard manure. Nitrogenous guanos are excellent manures for root and potato crops as well as cereals. Concerning the "phospho-Peruvian guanos" found in some of the islands of the West Indies, the late Dr. Voelcker stated that this manure "*is by far the most valuable fertilizer, whether natural or artificial, which as yet has been offered to the public.*" Voelcker recommended it especially for turnips, mangel-wurzels, and potatoes.

For wheat crops, from 2 to 3 cwts. of guano per acre forms an excellent manure when sown broadcast (either by hand or by the manure distributor, Fig. 9), and harrowed into the land before sowing the seed. Whenever

possible, guano should be sown in *damp* weather. Damp weather diffuses it in the soil.

For root crops, generally from 4 to 5 cwts. of guano per acre is a good dressing, especially for strong clayey soils. For grass lands, a mixture of superphosphate of lime and guano forms an excellent top-dressing.

It must not be forgotten that in one ton of *meadow*

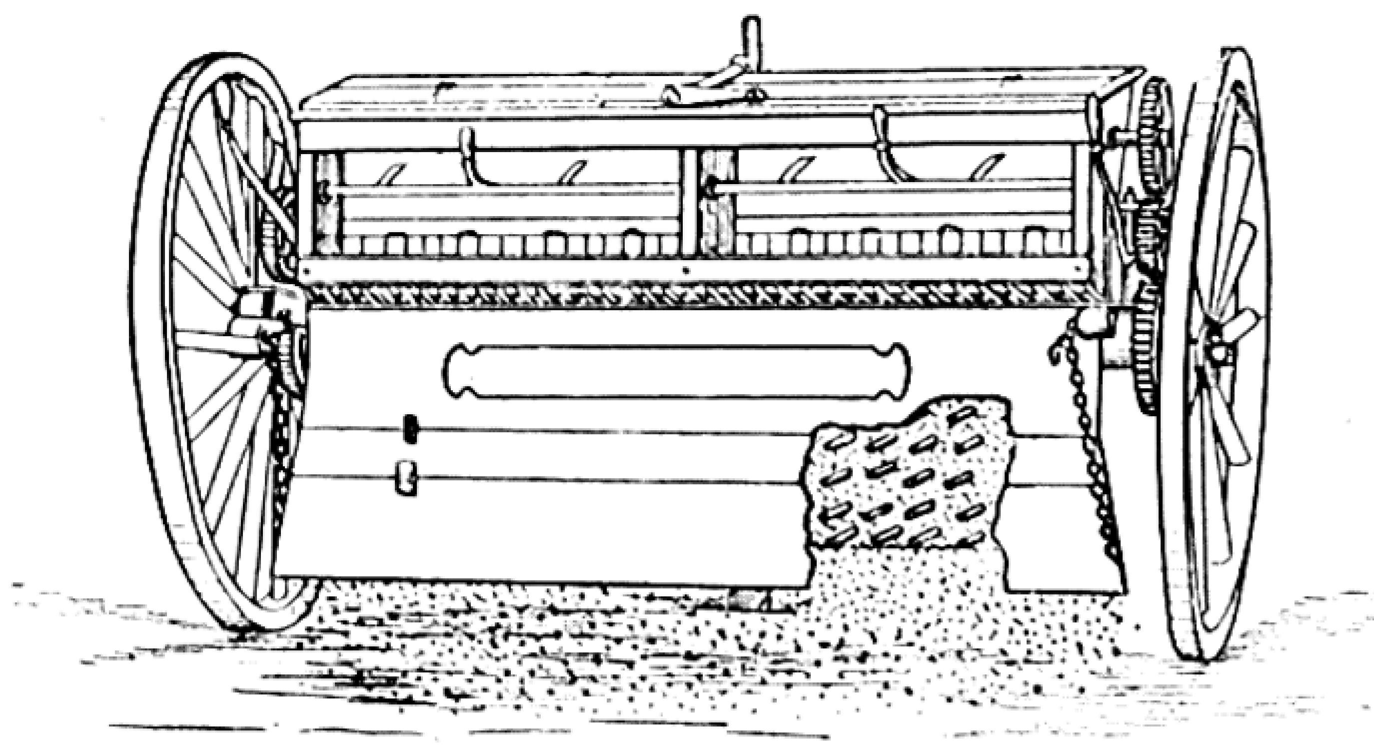

FIG. 9.—BROADCAST MANURE DISTRIBUTOR.

hay there are nearly 34 lbs. of nitrogen, 16 lbs. of phosphoric acid, and 36 lbs. of potash; consequently these important fertilizers must be given back to the soil if it is to remain fertile.

Peruvian guano has several advantages over other natural phosphates containing the same percentages of nitrogen and phosphoric acid, on account of its highly complex chemical condition, the nitrogen and phosphoric acid contained therein being each in several different forms and different degrees of solubility. For this reason it is more valuable as a plant-food. Peruvian

guano contains a portion of its nitrogen and phosphoric acid in the form of ammonium phosphate, which is an extremely soluble nitro-phosphatic substance. Another portion of the nitrogen is in the form of *insoluble* organic matter; while a portion of the phosphoric acid occurs as insoluble tricalcium phosphate.

Peruvian guano contains a *nitrogenous* substance called guanine. It is allied to urea, a substance found in the liquid excrements of animals. Guanine, like urea, undergoes a chemical change in the presence of water; the nitrogen being converted into ammonium carbonate. The formation of ammonium carbonate in Peruvian guano is not desirable, as it is a very volatile compound, and would pass into the atmosphere with loss of ammonia.

Therefore, those farmers who keep large quantities of Peruvian guano should see that it is stored in thoroughly dry places, or the agricultural value of the manure (through damp) is greatly reduced.

The next two tables give the composition of a variety of Peruvian and other *nitrogenous* guanos :—

PERUVIAN GUANOS.

	Punta de Lobos.	Pabillon de Pica.	Huanillos.	Chincha.	Guañape.	Ballestas.	Macabi.	Angamos.
Moisture	14·53	4·13	8·23	13·67	17·79	19·19	29·07	7·24
Organic matter + ammonia salts	35·77	59·01	46·46	52·05	42·62	48·19	39·06	69·01
Calcium phosphates	26·50	21·82	22·45	22·78	25·45	20·69	23·37	12·06
Alkaline salts	20·35	9·00	19·22	9·67	11·92	9·40	6·59	9·02
Sandy matter	2·85	6·04	3·64	1·83	2·22	2·53	1·90	2·67
	100·00	100·00	100·00	100·00	100·00	100·00	99·99	100·00
Phosphoric acid	—	11·67	15·62	13·78	—	—	—	—
Nitrogen	6·92	15·08	10·40	13·61	10·04	13·60	10·93	21·15
Nitric acid	—	0·04	2·87	—	—	—	—	—

OTHER NITROGENOUS GUANOS.

	Australia.	Texas.	Ichaboe.	Patagonia.	Falkland Islands.	Cape Town.
Water	15·067	20·10	17·40	35·86	33·43	—
Organic matter + ammonia salts	46·730	50·13	34·72	26·07	21·42	73·51
Calcium phosphate	—	—	21·40	22·01	32·04	17·50
Phosphoric acid	15·100	6·37	—	—	—	—
Lime	17·985	12·19	—	—	—	—
Alkaline salts, etc.	1·405	8·58	8·29	7·34	6·22	—
Sandy matter.	2·713	2·63	18·19	3·08	4·37	—
Calcium carbonate	—	—	—	5·64	2·52	—
	100·000	100·00	100·00	100·00	100·00	
Nitrogen	12·25	8·45	8·92	4·42	4·31	3·30

The guano of the Ichaboe Islands, near the south-west coast of Africa, is always being formed. It is collected by the inhabitants and placed in pits. By this means little nitrogen is lost by volatilization.

Ichaboe is distinguished from other guanos by the presence of a large quantity of minute feathers, which indicate that it consists of the dried excreta of sea-birds.

Texas guano is the pure excrements of large numbers of bats deposited in certain caves near the coast. The late Dr. Voelcker reported that Texas guano contains nitrogen in three distinct forms; viz., as organic matter, as ammonia salts, and in the form of nitrates. The two latter sources of nitrogen are readily available plant-foods; while the organic matter requires time for its decomposition. "Therefore, it forms a reserve or latent supply of nitrogen, which becomes *active* after a time."

"The greater part of the nitrogen contained in Peruvian guanos is in the form of uric acid and its salts, but small quantities exist as the base guanine, etc. This nitrogen is almost immediately available as plant-food, and is considered by some to have equal value with the nitrogen of the salts of ammonia, if not with sodium nitrate.

"The phosphoric acid of these guanos exists chiefly as finely divided calcium phosphate (tricalcium phosphate), but some of the phosphoric acid is in combination with alkalies like potash or soda.

"Agricultural experience does not, however, show that the guano of Peru is the most suitable form in which to supply nitrogen to *chalky* and *calcareous* soils. On these, nitrate of soda is generally a more suitable manure." The lime in these soils liberates ammonia from the nitrogenous substances, guanine, uric acid, etc.

The next table gives the composition of the chief "*non-nitrogenous*" guanos from various parts of the world:—

NON-NITROGENOUS GUANOS.

	Jarvis Island.[1]	Baker Island.[1]	Starbuck Island.[1]	Kooria Mooria.	Sidney Island.	Mejillones.	Bolivia.	Enderley Island.	Maldon Island.	Howland Island.
Water	11·8	10·0	11·56	18·1	7·38	13·87	10 0	8·76	4·50	10·01
Organic matter . .	8·2	9·2	7·25	12·4	7·29		21·7	8·81	6·64	5·72
= nitrogen . .	—	—	—	—	0·28	—	—	—	—	—
Lime phosphate . .	—	—	—	42·7	—	—	51·5	—	—	—
Phosphoric acid . .	20·6	34·8	33·61	—	34·41	33·79	—	28·74	37·58	34·21
Lime	39·1	41·5	41·04	—	42·96	30·61	—	40·76	43·51	43·03
Carbonic acid . . .	18·0	1·5	1·05	—	2·64	14·30	—	7·26	2·61	6·83
Magnesia, potash, etc.	1·2	2·9	5·47	—	2·79		—	5·58	4·33	
Alkaline salts . . .	—	—	—	4·2	—	—	14·1	—	—	—
Lime carbonate . .	—	—	—	4·1	—	—	—	—	—	—
Chlorine and fluorine	0·2	0·3	—	—	1·27	—	—	—	0·82	—
Sulphuric acid . .	—	—	—	—	1·63	—	—	—	—	—
Sandy matter . . .	0·5	0·8	0·02	18·5	—	7·43	2·7	0·09	0·01	0·20
	99·6	101·0	100·00	100·0	100 37	100·00	100·0	100·00	100·00	100·00

[1] The first three analyses are from Dr. E. Wolff's "Praktische Düngerlehre."

As a general rule, these guanos do not contain more than 0·3 per cent. of nitrogen, which is chiefly in the insoluble condition.

ADULTERATION OF GUANOS.

"Guanos, owing to their high price, are and have been greatly adulterated. The materials used for adulterating guanos are sand, clay, gypsum, salt, powdered bricks, and limestone. Imitation Ichaboe guanos have been made up of precisely the same colour as the original, with feathers added.

"Sometimes Peruvian guanos are adulterated with cheap mineral phosphates in a finely ground state. Such phosphates have not the same agricultural or money value as the phosphates, etc., contained in genuine Peruvian guanos."

The farmer who purchases guanos should insist upon having a written guarantee stating the percentages of nitrogen and calcium phosphate present; and if any doubt is entertained of the genuineness of the manure, it should be sent to an analytical chemist for analysis.

AMMONIATED PERUVIAN GUANOS.

This manure is ordinary Peruvian guano with ammonium sulphate added, the object being to make the ammonia equal to that found in a first-rate quality Peruvian guano. This "ammoniated" guano is sometimes called in the trade "equalized Peruvian guano."

Ohlendorff's "ammoniated" or "equalized" Peruvian guanos contain from 8 to 9 per cent. of nitrogen reckoned

as ammonia; from 30 to 35 per cent. of phosphates, and 2 per cent. of potash.

These guanos have been in extensive use for many years in England, France, Germany, and the British Colonies. Ohlendorff's brand is of uniform quality, and free from lumps and stones.

The "ammoniated" guanos are useful on all soils, except those derived from limestone and chalk rocks.

Coprolites and Pseudo-coprolites.

"Coprolites are found in various parts of the world, and some are said to consist of the fossilized bones and excrements of extinct mammals."

In England they are found in the form of nodules in the green-sand formation, the "Crag" of the eastern counties, and the chalk formation of the southern counties. These coprolitic rocks are of Tertiary age. It was through Professor Henslow that the public were first made acquainted with the valuable phosphatic nodules which occur in the sedimentary rocks of the east and south-east of England.

Henslow stated at the British Association meeting, held at Cambridge in 1845, that "a stratum of green sand, although never more than a foot thick, occurred near the surface over many square miles in the vicinity of Cambridge, and the pebbles it contained yielded 61 per cent. of earthy phosphate and 24 per cent. of carbonate of lime, the rest being insoluble matter."

In 1851, Dr. T. S. Herapath, F.R.S, wrote in his paper, "On the value of fossil bones and pseudo-coprolites of the Crag," as follows:—

"They are found in enormous quantities on the coasts

of Suffolk, Norfolk, and Essex, where several hundreds of persons are now actively employed in exhuming and collecting them with the view to their future conversion into artificial manures. It is from these counties, indeed, that Mr. Lawes, of Rothamsted, obtains nearly the whole of the material he employs in the preparation of his well-known 'Coprolite Manure,' and so extensive is the demand for this description of fertilizer for wheat and turnip-growing lands that several thousands of tons of fossil bones, etc., are annually sold in this country under one form or another, and the consumption of them is daily and rapidly increasing."

The following table shows the annual "output" of coprolites and phosphatic nodules, in the counties of Cambridgeshire, Bedfordshire, and Suffolk, from 1878 to 1886:—

Year.	"Output" in tons.	Money value.
1878	54,000	£150,000
1879	34,000	73,750
1880	30,500	70,950
1881	31,500	86,628
1882	49,500	97,500
1883	49,500	101,625
1884	51,800	103,900
1885	30,000	50,000
1886	20,000	31,500

"It is, however, evident that the production is decreasing, not so much because the deposits are becoming exhausted, as because Charleston and other phosphates are found to be better and cheaper for the manufacture of superphosphates."

The next table shows the composition of the English coprolites :—

COMPOSITION OF ENGLISH COPROLITES.

	Suffolk.	Cambridgeshire.	Bedfordshire.
Water	5·76	4·01	3·35
[1] Phosphoric acid	28·34	26·75	23·47
Lime	40·70	45·39	36·29
Magnesia	0·34	0·48	+
Iron oxide	4·87	1·87	5·39
Alumina		2·57	7·24 +
Carbonic acid	5·08	5·13	3·45
Sulphuric acid	0·87	1·06	—
Potash	0·78	0·84	—
Soda	0·25	0·73	—
Chlorine	Traces	Traces	—
Fluorine	3·00	4·95	+
Sandy matter	10·01	6·22	20·81
	100·00	100·00	100·00
[1] Equal to bone phosphate	61·30	57·12	51·24

From the recent experiments of Mr. B. Dyer, B.Sc., it appears that superphosphates are better suited for well-limed lands, and the *raw* coprolites for those lands containing only a small percentage of lime.

Mineral Phosphates.

The *mineral* phosphates which occur in other parts of the world are, for the most part, different from the coprolites of this country. For instance, the mineral phosphates of Canada cannot possibly have a *mammalian* or *saurian* origin, being found in Laurentian or the oldest

rocks, in the form of "pockets," due to deposition from solution.

"When found in the older rocks, mineral phosphates are either in a crystalline (apatite) or a non-crystalline (phosphorite) condition."

The first mineral phosphate raised for agricultural purposes was in the province of Estremadura in Spain.

Mineral phosphates are largely used in the manufacture of the cheap superphosphates of lime. The supplies of *mineral* phosphates are or have been obtained from the following parts of the world :—South Carolina, Canada, Norway, France, Germany, Spain, Algeria, Russia (coprolites), and Belgium.

The next table gives the composition of a number of mineral phosphates :—

MINERAL PHOSPHATES.

	Canada.	Norway.	Russia (*coprolites*).	Estremadura.	South Carolina.	France (*Bordeaux*).	Germany.
Water	0·11	0 90	3·55	0·68	1·56	4·80	1·78
Phosphoric acid . . .	37·68	35·69	22·42	36·36	26·89	35·51	35·73
(=Tricalcium phosphate)	(82·25)	(77·90)	(48·94)	—	(58·7)	(77·52)	(77·99)
Lime	51·04	46·39	33·84	42·68	42·28	47·81	44·22
Carbonic acid	—	—	—	—		5·06	1·65
Magnesia, potash, etc. .	6·88	1·10		8·81	18·47	3·81	
Iron oxide and alumina		2·82	9·94	—			13·14
Chlorine	—	1·62		—	—	—	
Sulphuric acid	—	0·29	—	—	—	0·64	—
Sandy matter	4·29	11·62	30·25	11·47	10·80	2·37	3·48
	100·00	100·43	100·00	100·00	100·00	100·00	100.00

(1) The Canadian phosphate (apatite), in a crystalline condition, is found in certain rocks of Palæozoic age. This phosphate is largely exported to England. During the year 1887 no less than 19,194 tons of Canadian apatite were used in England for the manufacture of superphosphate of lime.

The superphosphate obtained from Canadian apatite is largely used for the wheat-growing soils of that country.

(2) Norwegian apatite contains a considerable amount of silicious matter, but is almost free from carbonate of lime.

(3) Russian coprolites contain a high percentage of silica, and only 49 per cent. of tricalcium phosphate (bone phosphate).

The shipments of both Norwegian apatite and of Russian coprolites to this country have almost ceased, the latter on account of a heavy duty put on its exportation to other countries.

(4) The phosphates of the province of Estremadura (Spain) have long been known, but the mines have only been worked on a large scale about twelve or fourteen years. These deposits contain a considerable percentage of tricalcium phosphate, and have proved useful in the preparation of superphosphates of lime. Spain and Portugal exported, in 1887, 15,612 tons of mineral phosphates to this country.

(5) The South Carolina phosphates are of Eocene age, and are therefore not so "mineralized" as the Canadian and Norwegian phosphates which occur in the oldest formations. These phosphates were discovered about twenty years ago, and up to the present time 4,500,000 tons have been exported to Europe.

There are two varieties of Carolina phosphate; viz.,

"the river phosphate" and "the land phosphate." The former is obtained by dredging the various rivers of South Carolina, and is of a higher agricultural value than "the land phosphate." During the last few years about two-thirds of the British supply of phosphate has come from this part of the world; and as its price has been low, manure makers have been able to manufacture a cheap superphosphate of good quality.

(6) French phosphates, or the phosphates raised in the departments of Tarn-et-Garonne, Lot, Lot-et-Garonne, etc., were formerly exported to Great Britain, but the importation has now almost ceased. These phosphates contain a certain amount of iron oxide and alumina, and "therefore find a better market in France, where these constituents are not so much objected to, because phosphoric acid, whether soluble in water or only in citrate of ammonia, is considered of almost equal value."

Recently phosphates of good quality and suitable for the English market have been raised in the departments of the Somme and d'Oise in the north of France. These deposits are of the Chalk age, and contain from 50 to 80 per cent. of phosphate of lime. The quantity raised during 1888 was about 150,000 tons.

(7) The German phosphatic deposits have been worked since 1864. They are largely used in Germany for the preparation of superphosphates, but are of little value for the preparation of manures in England. German phosphates contain too high a percentage of alumina and iron oxide for the preparation of a *good* quality superphosphate.

(8) Belgian phosphates have been used in this country for some years. The deposits occur near Mons, "in the so-called pockets, which are circular indentures in the

rock; some also are found in the shape of rock, the so-called '*craie grise*,' or phosphatic chalk."

Belgian phosphates contain from 35 to 40 per cent. of tricalcium phosphate. The phosphates raised near the Bois d'Havré are of better quality, containing from 55 to 65 per cent. of tricalcium phosphate. The quantity of Belgian phosphates raised in 1886 was about 145,000 tons.

Crust Guano.

The island deposits previously named under Peruvian and other guanos "all supply guano in a powdery form, the actual droppings of birds more or less washed out; whilst there are others, such as Sombrero, Curaçao, Aruba, Mexico, Navassa, and Cayman, which supply soft rock phosphate, the *crust guano* of commerce."

"The origin of most of these phosphates is probably, to some extent, bird deposits, but having been for a long time in contact with coral rock, the carbonate of lime has been converted into phosphate of lime, and the phosphate is now found as a rock."

The next table gives the composition of a few of these phosphates:—

CRUST GUANO.

	Aruba.	Sombrero.	Navassa.	Curaçao.
Water	5·55	8·67	5·91	8·72
Organic matter	—	—	5·46	5·79
Phosphoric acid	31·11	32·45	31·18	33·51
Lime	41·69	46·11	37·70	43·01
Magnesia, iron oxide, etc.	14·72	4·29	13·29	5·71
Carbonic acid	6·69	7·33	2·38	2·96
Sulphuric acid	—	—	1·16	—
Sandy matter	0·24	1·15	2·92	0·30
	100·00	100·00	100·00	100·00

(1) Sombrero and Curaçao Islands produce some of the purest phosphates known in the manure trade.

(2) The phosphates from the other West Indian Islands yield from 60 to 80 per cent. of tricalcium phosphate.

As stated before, the chief use of mineral phosphates is in the preparation of superphosphates of lime; but for soils rich in organic matter, "ground" mineral phosphates have proved excellent dressings. From 7 to 10 cwts. per acre of "ground phosphate" have been recommended for barley. For pasture land these manures have proved useful, when applied at the rate of 10 cwts. per acre.

Thomas Phosphate.

Thomas phosphate, basic slag, or basic cinder, is a product formed during the conversion of cast-iron into steel by what is known as the "basic process."

During the year 1887, Great Britain produced 106,000 tons, and Germany 262,000 tons of basic cinder. Basic cinder contains from 9 to 26 per cent. of phosphoric acid, while a *good quality* slag should contain from 16 to 26 per cent. of phosphoric acid.

The following are comparatively recent analyses of this new source of phosphoric acid for agricultural purposes:—

THOMAS PHOSPHATE.

	Analysts.		
	Wrightson and Munro.	A. B. Griffiths.	Stead and Ridsdale.
Lime	41·54	45·04	47·34
Magnesia	6·13	6·20	6·01
Ferrous oxide	14·66	11·64	12·72
Ferric oxide	8·64	5·92	2·07
Manganous oxide	3·81	3·51	3·43
Alumina	2·60	1·72	1·43
Phosphoric acid	14·32	18·11	19·19
Sulphuric acid	0·31	0·41	Trace
Sulphur }	0·23	0·30	0·51
Calcium }	—	—	0·41
Vanadium oxide	0·29	0·24	1·19
Silica	7·40	6·90	5·76
	99·93	99·99	100·06

It appears that the *whole* of the phosphoric acid is in the form of tetracalcium phosphate (tetrabasic phosphate of lime), which is far more soluble than either bone or retrograde phosphates. According to Professor Wagner ("Der Düngewerth und die rationelle Verwendung der Thomas Schlacke," 1888), finely divided basic slag (*tetra*-calcium phosphate) is soluble in carbonic acid water to the extent of 36 per cent., while similarly treated phosphorite (*tri*calcium phosphate) is soluble only to the extent of 8 per cent.

This proves that the lime phosphate which basic slag contains is a readily available source of phosphoric acid, easily taken up in solution by the rootlets of growing crops.

Rain-water and the moisture of all soils contain carbonic acid gas in solution; therefore this moisture is

capable of dissolving the tetrabasic lime phosphate contained in basic slag; this, in its turn, supplies the growing crops with phosphates requisite for their proper development.

Thomas phosphate (although it has been in the manure market for the past half-dozen years) has not had the approval of the British farmer it merits. In the words of Mr. R. Warington, F.R.S.:—"Basic slag has been little used in England, chiefly in consequence of the prejudice of the English farmer against anything new, and not because our soils are unsuited to it. I can recollect Sir John Lawes saying that, in years gone by, when he changed his material for making superphosphate from animal charcoal, which gave a dark blue colour, to coprolite, which produced a pale brown manure—that it was difficult to get the farmers to take the new manure, *as they thought the virtue lay in the dark colour* (!!). The Germans, the Danes, and, in fact, the *farmers* of most Continental nations are getting ahead of the British farmer, simply because they understand better the principles that underlie their work."

It is a misfortune for farmers to stand in their own light; for after superphosphates, Thomas phosphate powder is the most readily available source of phosphoric acid for agricultural purposes.

"Farmers cannot afford to use a phosphatic manure which will have scarcely any immediate action on their crops. They naturally want as quick a return—in the shape of heavy crops—from the money they invest in manures as is possible. On this account they prefer and pay more for a *quickly acting* manure than one that acts more slowly" (Aikman). Therefore, for this object, where a *good* as well as a *cheap* source of phosphoric acid is

a *desideratum*, the farmer cannot do better than use Thomas phosphate powder.

Thomas phosphate should only be purchased in the form of an *impalpable powder*, and guaranteed to contain from 16 to 20 per cent. of phosphoric acid. Recently in Germany a slag has been produced containing from 25 to 26 per cent. of phosphoric acid, and is sold to farmers under the name of "patent phosphate meal."

According to a large number of experiments made in this country and in Germany, the phosphoric acid contained in Thomas phosphate is *half as valuable* as that contained in superphosphate of lime.

Thomas phosphate powder ought to be ploughed into all arable soils, so as to be near the roots of the crop,—simply harrowing is insufficient.

The soils best suited for this manure are those of a peaty or of an organic nature. There is little doubt that this valuable and unlimited source of phosphoric acid would prove highly beneficial on the soils of the fen districts of this country.

On the German *moorland soils* Thomas phosphate has proved equal to, if not better than, superphosphates for barley, oats, potatoes, and sugar-beets; and it is a cheaper source of phosphoric acid than superphosphates.

Professor Wagner recommends 4½ cwts. of Thomas phosphate per acre as the quantity to be applied to the land; while Professor Wrightson recommends from 6 to 10 cwts. per acre. The latter, of course, would be a very liberal manuring.

Thomas phosphate may be mixed with raw phosphates, superphosphates, nitrate of soda, potash salts, etc., but *not* with ammonium sulphate, as the *free* lime which it (Thomas phosphate) contains would liberate the

ammonia, and result in loss of this valuable nitrogenous manure.

During the year 1888, a valuable series of experiments were made by Mr. J. Mason, at Eynsham Hall, Oxfordshire,[1] on the comparative value of *Thomas phosphate* and other fertilizers.

The crop was wheat; and 27 plots of land of an acre each were used to compare the results from a pecuniary standpoint of dung, Thomas phosphate, lime and superphosphate.

For the *two first-named* dressings several duplicate plots were provided, and there were also six separate plots left unmanured. Five of the plots were manured as follows:—

No. I., with 14 loads of good farmyard manure.

No. II., with 14 loads of dung, and a subsequent top-dressing of 168 lbs. of nitrate of soda.

No. III., with 16 cwts. of Thomas phosphate, followed by a top-dressing of 302 lbs. of nitrate of soda.

No. IV., with 8 cwts. of Thomas phosphate, followed by a top-dressing of 302 lbs. of nitrate of soda.

No. V., with 8 cwts. of Thomas phosphate, and no top-dressing.

In working out the *money* part of the experiments, the value of the head corn was reckoned at 3*s.* 10½*d.* per bushel, the tail corn at 3*s.* per bushel, and the straw at 35*s.* per ton. The seed used was estimated at 12*s.* per acre, and rent and taxes at 24*s.* The labour bill was highest on plot No. II., which received 14 tons of farmyard manure and a top-dressing of nitrate of soda; and it

[1] The results were published by the experimenter.

may be noted that as the land had only lately been taken in hand, there was an expenditure of 15*s.* per acre for labour above that which would have sufficed under normal conditions. Plot No. II. gave the largest crop, the total produce being 67 cwts. 100 lbs., representing a money value of £12 14*s.* 9¼*d.*; the total cost of production, less management charges, being £12 15*s.* 8*d.*, of which amount £4 4*s.* 2*d.* was paid for manure; the expenditure thus showing a *loss* of 10¾*d.* per acre.

The Thomas phosphate, on the other hand (8 cwts.), with a top-dressing of nitrate of soda, yielded produce to the amount of 66 cwts. 100 lbs., valued at £12 19*s.* 5½*d.*; while the total cost of production was £10 13*s.* 8*d.*, leaving a clear profit of £2 5*s.* 9½*d.* per acre. It is a noteworthy fact that 8 cwts. of Thomas phosphate, with a top-dressing of nitrate of soda, was more efficacious than 16 cwts. of the phosphate with the same amount of nitrate of soda. This shows that farmers can easily *over-manure* their lands with no material benefit to the crop or crops grown.

The produce from plot No. V., manured with 8 cwts. of Thomas phosphate *alone*, left a clear profit of £1 1*s.* 7*d.* per acre.

In all the "Eynsham experiments" where Thomas phosphate was used, the result was a *profitable one*. From these experiments it is obvious that Thomas phosphate or finely ground basic slag must be considered an important fertilizer for *wheat* crops. There are several reasons why Thomas phosphate should be used by farmers in preference to other raw phosphates:—

(*a*) It is cheaper and more soluble in rain-water, and therefore a direct plant-food.

(*b*) It is a *home* product; and to all interested in the development of our home industries, Thomas phosphate

should be used in preference to foreign coprolites, phosphates, etc.

(*c*) "It is not the aim of the farmer to produce the greatest crops irrespective of profit or loss, but to realize the utmost *clear profit*." Thomas phosphate, when judiciously used, in respect to quantity and quality, produces a clear profit for all crops requiring phosphatic manures.

(*d*) Thomas phosphate may be either sown broadcast (by hand or machine), or drilled in with the seed, or ploughed into the soil as recommended by Dr. Wagner.

(*e*) The after-action of Thomas phosphate in the soil surpasses largely the after-action of superphosphate of lime.

It is a great misfortune to British agriculture that farmers, so far, have ignored the benefits to be derived from applications of this all-important source of phosphoric acid.

The British farmer appears to be prejudiced against any innovation in the agricultural art.

About fifty years ago, the late Sir Robert Peel presented a Farmers' Club at Tamworth with two iron ploughs of the best construction. "On his next visit the old ploughs with the wooden mould-boards were again at work. 'Sir,' said a member of the club, 'we tried *the iron*, and we be all of one mind that they made the weeds grow!'"

In these days iron ploughs are the only ones used; still there is the same amount of prejudice in other directions.

If once and for ever this prejudice could be buried in oblivion, we should find British agriculture making the same progress as is found in the great technical industries of this country.

To conclude the chapter, in the words of Dr. Leone Levi:[1]—"Some writers used to distinguish agriculture from industry, the one being intent upon the extraction of produce from the soil, the other upon the shaping, converting, or manufacturing what nature supplies. *But it is not so.* Agriculture and manufactures are both industries requiring alike labour, skill, and capital. In England, the divorce is indeed complete; but they had better look keenly to one another, and each draw from the other the lessons which it needs."

[1] "Work and Pay," p. 19.

CHAPTER VII.

ARTIFICIAL MANURES (*continued*).

THIS chapter is devoted to detailing the various artificial *nitrogenous* manures, and the best methods of applying them to the land.

NITROGEN NECESSARY FOR PLANT-LIFE.

Nitrogen is essential to the growth of crops. *Without nitrogen no growth.* The following table shows the amount of this element removed from the soil during the growth of farm crops:—

1	ton of	beans	removes	89·6	lbs.	of nitrogen	from	the soil.
1	,,	barley	,,	36·9	,,	,,	,,	,,
1	,,	wheat	,,	40·3	,,	,,	,,	
1	,,	oats	,,	44·8	,,	,,	,,	
1	,,	tares (seed)	,,	94·0	,,	,,	,,	,,
1	,,	clover	,,	53·7	,,	,,	,,	,,
1	,,	meadow-hay	,,	33·6	,,	,,	,,	,,
1	,,	peas	,,	80·6	,,	,,	,,	,,

Nitrogen "is an element as necessary to the cultivated plant as sunshine and rain. It enters into the formation of roots, leaves, wood, and seed, and is at the same time an element of that organic substance, protein (*albumin*), the production of which is the principal object of agriculture."

Apropos of the importance of nitrogenous manures for the growth and development of farm crops, the following axioms are of the utmost importance:—

(1) "No crop can flourish without obtaining nitrogen by its roots, *i.e.*, without a supply of nitrogen from the soil."

(2) "If the soil is *not* supplied with nitrogen, it cannot yield a crop at all satisfactory to the farmer; therefore nitrogenous manure is an indispensable factor in rational agriculture."

(3) "The manure produced on the farm is in very few cases sufficient to supply the cultivated plant with the nitrogen it requires to produce crops securing *the highest possible clear profit.* The practical farmer must therefore have recourse to artificial manures."

(4) "Dry, light soils require less phosphoric acid and more nitrogen and potash, while a damp, heavy soil needs the phosphoric acid to predominate."

(5) "Barley and rye need less nitrogen manure than oats and wheat; the former are more prone 'to lie' than the latter. Very small quantities of nitrogen must be given with barley if it is to be used for brewing; but if, on the other hand, it is to be used for distilling, its quality will not be injured by a heavy manuring with nitrate of soda."[1]

The principal nitrogenous (artificial) manures used in farming are as follows:—

(1) Nitrate of Soda.

Sodium nitrate (cubic nitre, Chili saltpetre, $NaNO_3$) is essentially a *nitrogenous* manure, containing, when pure, 16·4 per cent. of nitrogen.

It occurs in extensive deposits in certain districts of Chili, Peru, Bolivia, and other parts of South America. Nitrate of soda occurs in the sedimentary formations of Peru, and is found between a layer of sand (containing

[1] Stutzer's "Nitrate of Soda: Its Importance and Use as Manure" (Whittaker & Co.).

gypsum), called "chuca," and a conglomerate of clay, fragments of porphyry and felspar, cemented together with gypsum and other sulphates, called "costra" (Fig. 10). The layers of nitrate of soda ("caliche") found between the "chuca" and "costra" are from 1 to 16 feet thick, a hundred or more miles in length, and lie from 1½ to 10 feet below the surface.

"The regions in which the nitrate is found are quite destitute of vegetation. There is often no rain for three or five years, and even then so little that the surface is hardly moistened." The nitrate of soda of Peru occurs on the plateaus of the province of Tarapaca, and is the final product of the process of nitrification from sea-weeds.

According to Roscoe and Schorlemmer, the *crude* nitrate contains from 27 to 65 per cent. of $NaNO_3$ mixed with gypsum, salt, sodium sulphate, etc., and is purified by lixiviation with water followed by evaporation.

The following table shows the composition of ordinary *commercial* nitrate of soda :—

	Analysts.			
	Mr. H. Follows, F.C.S.		Messrs. Hudson Brothers.	
	I.	II.	I.	II.
Nitrate of soda . . .	96·45	97·45	96·70	97·60
Chloride of soda . .	0·62	0·37	1·30	1·20
Sulphate of soda . .	0·44	0·30	0·10	0·10
Water and insolubles	2·49	1·88	1·90	1·10
	100·00	100·00	100·00	100·00
[1] Refraction	3·55 per cent.	2·55 per cent.	3·3 per cent.	2·4 per cent.

[1] Refraction = total impurities.

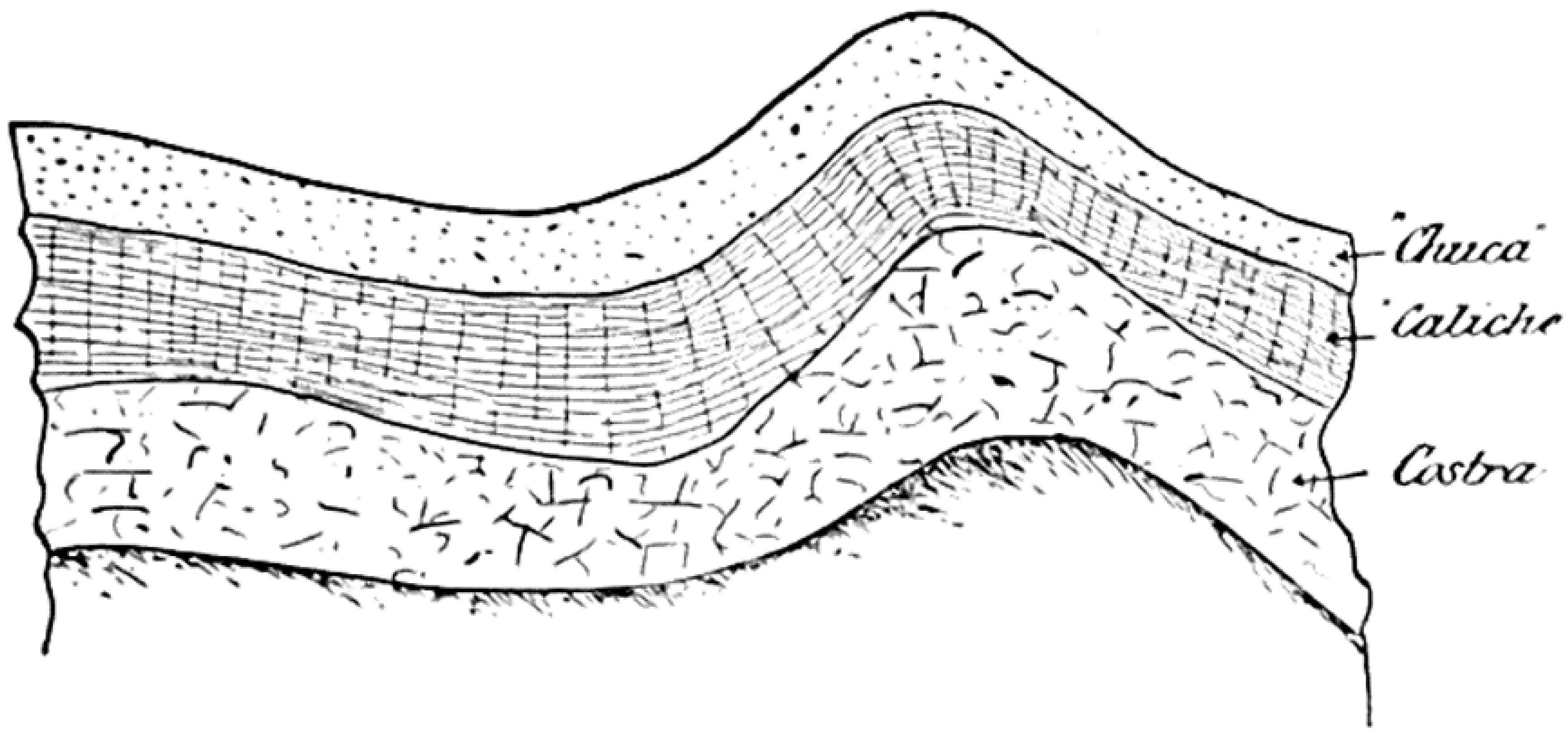

FIG. 10.—DIAGRAM OF NITRATE OF SODA DEPOSITS.

A *good* quality nitrate should contain at least 95 per cent. of pure nitrate. Nitrate of soda is sometimes adulterated with common salt, sodium sulphate, and other substances. The farmer should insist upon having a nitrate with a purity of not less than 95 per cent., as this contains 15¾ per cent. of nitrogen, equal to 19 per cent. of ammonia, or an allowance should be made for a lower quality.

Nitrate of soda is a valuable manure for all *straw-growing plants*, rape, mustard, sugar-beets, potatoes, meadow grasses, etc. As the mean results of a large number of experiments performed in a variety of soils and under various climatic conditions, every 1 cwt. of nitrate of soda produces a return of 3 cwts. of grain and 5 cwts. of straw, and yields a clear profit of over 115 per cent.

For *meadow land* nitrate of soda can only be *profitably* used, under certain favourable conditions of soil and climate. Before applying costly nitrates the farmer should carefully look into these conditions. Messrs. Lawes' and Gilbert's experiments show "that nitrate of soda is *unprofitable* as a manure (for meadows) with the soil and climate of Rothamsted."

In other parts of this country top-dressings of nitrate of soda for meadow and pasture lands have proved of the greatest value.

Nitrate of soda being a very soluble manure, it is always best to use it as a top-dressing when the crop is beginning to come up.

All *cereal* crops growing on British soils should be supplied with nitrogen, phosphoric acid, etc., between certain limits. Some soils require more nitrogen, etc., than others; but nearly all British soils require either a maximum, or a medium, or a minimum amount of

nitrogen, phosphoric acid, and potash for the growth of cereals.

The following table shows the extent of these limits:—

	A "Maximum" Manure.	A "Medium" Manure.	A "Minimum" Manure.
	Per acre.	Per acre.	Per acre.
Nitrate of soda . .	3 cwts.	1½ cwt.	¾ cwt.
Superphosphate of lime	3 "	2 "	1½ "
Potassium chloride	1½ "	¾ "	½ "

Taking into consideration the nature of the soil and the crops to be grown, the farmer must judge for himself which of the above is suitable for any particular case.

Let him bear in mind: (1) That wheat and oats require more nitrogen than rye and barley. (2) That a dry light soil requires more nitrogen and potash than a damp heavy one. (3) That organic soils, or those rich in humus, require more phosphoric acid and less nitrogen than soils poor in organic matter. (4) If the previous crop was what is known as a "*nitrogen-gatherer*,"[1] a less quantity of nitrogen is required for the next crop. (5) If the previous crop was a "*nitrogen-consumer*,"[2] a maximum manure of nitrogen is essential to keep the land in a fertile condition.

From the above remarks, the farmer will observe that to use more than 3 cwts. of nitrate of soda for cereal crops is so much waste money. The nitrate is not retained in the land after the first year of its application. Quoting from the author's "Treatise on Manures," let farmers bear in mind that—

[1] Clover, tares, lucerne, beans, peas, and leguminous crops generally are "nitrogen-gatherers."

[2] Cereals, potatoes, beetroots, etc.

"Over-manuring and under-manuring are mistaken principles in British agriculture."

It has been shown "that it is better to use nitrate of soda in fractional top-dressings, as the crops progress in growth, rather than at one time; a larger yield is thereby obtained."

If the dressing consists of 1½ cwt. of nitrate of soda per acre for wheat, it should be divided into three instalments of 56 lbs. each, and each instalment applied in March, May, and June respectively.

By *fractional top-dressings* the author obtained 50 bushels of grain against 42 bushels of grain when 1½ cwt. of nitrate of soda was applied in one instalment.

"There is little doubt that fractional top-dressings of the more soluble manures is the most economical way of applying them, and the *profit* derived from this method is far in excess of the small additional cost of, say, three applications."

Nitrate of soda is not only a direct but an *indirect* plant-food. It has the power of hastening the nitrification of insoluble organic matter contained in soils; and according to Dr. Fiedler it favours the absorption of the phosphates.

The experiments of Lawes and Gilbert prove that the manurial effect of nitrates is always increased by the addition of phosphatic manures and potash. It was found that for every 1 cwt. of nitrate of soda used without phosphates the yield was less than when phosphates had been used as well; and the return (in money value) from nitrate combined with phosphoric acid is always greater than that from nitrate alone.

The following table represents the results of a few of the Rothamsted experiments. Each crop was manured

with the same amount of nitrates, but *with* and *without* phosphatic manures :—

Crops.	Manures.	Yield.
(1) Wheat (average of 33 years)	With phosphates .	239 lbs. corn and 623 lbs. straw
	Without ,, .	111 ,, ,, ,, 296 ,, ,,
	Excess with ,, .	128 ,, ,, ,, 327 ,, ,,
(2) Oats (average of 5 years)	With phosphates .	231 lbs. corn and 466 lbs. straw
	Without ,, .	197 ,, ,, ,, 369 ,, ,,
	Excess with ,, .	34 ,, ,, ,, 97 ,, ,,
(3) Barley (average of 16 years)	With phosphates .	541 lbs. corn and 1028 ,, ,,
	Without ,, .	317 ,, ,, ,, 827 ,, ,,
	Excess with ,, .	224 ,, ,, ,, 201 ,, ,,

Of course the farmer must in every case first ascertain the requirements of the land and crop to be cultivated before manures are applied. "Nitrate of soda can only produce its full effect when phosphoric acid, potash, and *other nutrient substances* are present in sufficient quantity."[1]

(2) Ammonium Sulphate.

Sulphate of ammonia is a home product, obtained as a *bye-product* in the manufacture of gas, "oven-coke" (for metallurgical and other purposes), shale oils, and other industries.

The ammoniacal liquor which is really the bye-product obtained in the above industries contains ammonia which is driven off (in the form of ammonia gas) and finally absorbed by sulphuric acid contained in lead-lined tanks.

[1] This remark applies to other manures as well as nitrate of soda.

Sulphate of ammonia for agricultural purposes should contain from 19 to 21 per cent. of nitrogen, which is equal to 23 to 25 per cent. of ammonia, and not more than 2 per cent. of impurities.

The following analysis represents a *good* sample of this manure :—

Moisture	6·59	
Sulphate of ammonia .	91·94	= 19·5 per cent. of nitrogen.
Impurities	1·47	
	100·00	

Sulphate of ammonia is suitable for all soils (requiring supplies of nitrogen), except those derived from chalk and limestone formations. Sulphate of ammonia should *not* be used on any soil containing more than 10 per cent. of carbonate of lime. If the farmer uses this source of nitrogen for soils containing much carbonate of lime, the ammonia from the sulphate volatilizes into the atmosphere. For all chalky soils, nitrate of soda is the nitrogenous manure to be used.

Sulphate of ammonia is a most valuable manure for clayey and loamy soils, especially when mixed with *insoluble* phosphates.

Drs. Märcker, Schultze, and others have shown that sulphate of ammonia increases the percentage of sugar in sugar-beets, while nitrate of soda decreases the quantity of sugar in the roots.

For barley required for malting purposes, sulphate of ammonia is a better nitrogenous manure than nitrate of soda.

Nitrate of soda increases the albuminoids (flesh-formers) in various crops (such as oats, rye, wheat, etc.), and hence enhances their value as foods. Sulphate of ammonia, as

a general rule, has a tendency to increase the carbohydrates (fat-producers) in plants.

For potatoes, both nitrate of soda and sulphate of ammonia are good manures, especially if the nitrate or sulphate is used in *fractional* top-dressings. It has been stated that *nitrates* have a tendency to lessen the percentage of starch in potatoes (on which depends the mealiness of potatoes); but the quantity of starch depends on "the conditions of climate, soil, and season, rather than on the manure."

For beans, peas, clover, and other leguminous crops, nitrate of soda is a far more valuable manure than sulphate of ammonia.

Sulphate of ammonia is a good manure for turnip and mangel-wurzel crops, especially when mixed with bones and wood-ashes.

"On corn or grass land, 1½ cwt. of sulphate of ammonia is generally the quantity recommended as a top-dressing after early spring growth has commenced."

Both sulphate of ammonia and nitrate of soda are quicker in their action than the various organo-nitrogenous manures. They are quicker in action because they are more soluble, and easily becom eplant-foods capable of being absorbed by the rootlets of plants. The majority of organo-nitrogenous manures have to undergo a change (nitrification) befote they become plant-foods.

Neither nitrate of soda nor sulphate of ammonia has any tendency to exhaust the soil. Upon this point the experiments of Drs. Beseler and Märcker (*Zeitschrift des landw. Centralvereins für die Provinz Sachsen*, 1884, p. 4) give a plain answer.

Sulphate of ammonia is more readily "fixed" in most soils than is the case with nitrate of soda. The ammonia

compound is easily absorbed by clayey and organic matter contained in soils.

Nitrate of soda, on the other hand, is more readily distributed (by rains and moisture) than sulphate of ammonia, which becomes "located" in the soil.

Sulphate of ammonia is more suitable than nitrate of soda for autumn and early spring use.

(3) Ammoniacal Liquor.

This liquid can be obtained from gas-works if near to the farm.

As a general rule, ammoniacal liquor should be diluted with four or five times its bulk of water.

It has proved a useful liquid manure for grass lands and cereals growing on clayey soils. The liquor can be applied by a water-cart.

Ammoniacal liquor absorbed by sawdust, peat, etc., and then mixed with bone-dust, forms an excellent manure for turnip and potato crops when applied in the drills.

(4) Nitrate of Potash.

Potassium nitrate, saltpetre, nitre (nitrum [?] of ancient writers) is a natural product occurring on the surface of the soil in India, Peru, Chili, Spain, Portugal, and other hot countries.

It is prepared, to a certain extent, artificially in France, Germany, and other parts of Europe.

England obtains its supply chiefly from the East Indies, our annual importations being over 30,000 tons.

The name *nitrum* is of great antiquity, and appears to have been conveyed from China to Egypt and Greece; and thence to Italy and other parts of Europe. It is

mentioned in Jeremiah ii. 22 and Proverbs xxv. 20, and in the writings of the Alexandrian school of philosophers.

Both Theophrastus and Pliny describe the similarity of wood-ashes (which contain potash) to nitrum. Yet there is plenty of evidence among classic writers to show that the *nitrum* of the ancients was our *natrum* (nitrate of soda) and not our saltpetre (nitrate of potash).

Pliny, Virgil, and Columella mention the use of nitrum as a manure for cabbages, radishes, and fruit-trees.

Nitrate of potash is produced (like nitrate of soda) by the process of nitrification. When pure, it contains 53·41 per cent. of nitric acid (equal to 13·8 per cent. of nitrogen) and 46·59 per cent. of potash.

Commercial nitrate of potash should contain from 12 to 13 per cent. of nitrogen.

This manure supplies the land with both nitrogen and potash, but it is far too dear to be used to any great extent for agricultural purposes. The majority of countries require their supplies of nitrate of potash for the manufacture of gunpowder, etc., which prevents its use as a manure.

On the authority of Dr. Nessler of Karlsruhe, nitrate of potash is a good manure for tobacco.

For flowers and small plants requiring nitrogen and potash, this manure is of no mean value.

(5) Soot.

Soot is a carbonaceous substance containing a small percentage of nitrogen. According to a certain analysis, a sample of soot contained 43·09 per cent. of organic matter, including nitrogen equal to 3·54 per cent. of ammonia. As a rule, the nitrogen reckoned as ammonia varies from 1 to 5 per cent.

Soot forms a good top-dressing for spring wheat and grass land. It is also a good manure for oats, roots, peas, asparagus, and other vegetables.

The usual dressing is from 40 to 65 bushels per acre.

In concluding the chapter, it may be stated that in the majority of cases, nitric acid (*i.e.*, nitrates) is the most advantageous nitrogenous food for farm crops. According to recent researches, organic nitrogen, and nitrogen as ammonia, are both transformed by certain microbes (present in soils) into nitric acid.

M. Miquel estimated that there exists in one gramme (15·43 grains) of the surface soil at Montsouris an average of 750,000 microbes; while in the soils of the Rue de Rennes and the Rue de Monge (Paris) there were no less than 1,300,000 and 2,100,000 respectively.

From these remarks the farmer will observe that both nitric acid (as nitrates) and ammonia salts are far more valuable sources of nitrogen than either farmyard manure or the various animal substances. Farmyard manure and other organic nitrogenous manures are either *insoluble* or not readily soluble in water, and therefore cannot possibly be absorbed by the rootlets of plants.

CHAPTER VIII.

ARTIFICIAL MANURES (*continued*).

In this chapter will be found an account of the principal *potash* manures.

These manures supply the soil with potash, and, if kainit is used, with sulphuric acid as well.

The ashes of many farm crops contain a large amount of this ingredient. For instance, those of the potato (tubers), bean, mangel-wurzel, and meadow-hay contain 53·55, 42·48, 46·69, and 21·92 per cent. of potash respectively.

Every plant requires a certain amount of potash for its growth and development. Potash, according to Sachs, plays an important part in the "nutrition" of chlorophyll, and its presence is absolutely indispensable to the formation of starch in the green leaves of plants. When a plant does not absorb potash, its vitality is greatly impaired; and crops growing on soils *deficient* in this ingredient run the risk of becoming diseased. Sickly plants are always more liable than healthy ones to the attacks of vegetable and animal parasites.

Although most soils are benefited by *small* dressings of potash manures, yet over-manuring with this substance is as bad as under-manuring, or leaving the soil with an insufficiency of this ingredient. The author has shown that an *excess* of potash manures has a tendency "to foster the development of parasitic fungi" (*Chemical News*, vol. liii. p. 256)

Some soils contain from 2 to 3 per cent. of potash, but the average is about 0·2 per cent. of this ingredient. Certain barren soils contain only 0·01 per cent., although this barrenness may be associated with a want of other ingredients besides potash.

One ton each of peas, wheat, clover-hay, and barley removes 21·5, 11·87, 33·6, and 12·32 lbs. of potash respectively from the land. This ingredient must be replaced, in suitable quantities, if the soil is to remain in a fertile condition.

Therefore, it is essential for the farmer to know exactly the requirements of the land under cultivation.

(1) Kainit.

Certain saline deposits containing potash are mined in various parts of Germany, especially in the vicinity of Stassfurt and Leopoldshall.

One of these substances is *Kainit*, containing about 24·43 per cent. of potassium sulphate. Kainit also contains sodium chloride (salt), and the sulphate and chloride of magnesium.

A *good* quality kainit should contain from 12 to 14 per cent. of potash.

Kainit is better mixed with phosphatic and nitrogenous manures (see last chapter) than used alone.

"With regard to the question of *potash* manures for *cereals*, it is a mistake to think that it is less suitable for them and other farinaceous plants than for any other crop. . . . If the soil is at all poor in potash, cereals will reward potash manures as well as any crop. It must also be remembered that potash will not only effect a better *nutrition* of cereals, but together with a plentiful

supply of nitrogenous manure it will counteract a possible injurious consequence arising from heavy manuring with phosphoric acid; namely, the premature dying (the so-called '*burning*') of cereals, during a dry and hot season" (Stutzer).

In *dry* seasons kainit increases the percentage of sugar in sugar-beets.

For pastures 2 cwts. of kainit per acre have proved an excellent top-dressing when applied in the spring in *dry* weather. On soils derived from limestone or chalk rocks, potash salts are best applied in the autumn; and for grass lands in fen districts the kainit should always be mixed with guano.

Kainit has also proved a good manure for clover, beans, peas, potatoes, and mangel-wurzels.

From a large number of experiments made with *cereals* growing in *heavy* soils, it appears that potash manures had very little or no beneficial results. This does not prove that cereals do not require potash manures; on the contrary, they are of the utmost importance for these crops on all soils deficient in this ingredient. As a general rule, *heavy* soils are rich in potash; therefore, to add potash when the soil has an abundance is, to say the least, an extravagant procedure.

Potash salts enter very largely into the various "mixed" or "special" manures made by manure manufacturers.

(2) Carnallite.

Kainit is essentially a double sulphate of potash and magnesia; carnallite, on the other hand, is a double chloride of potash and magnesia. Kainit is a better potash manure than carnallite. The latter contains,

when pure, 38·2 per cent. of *chlorine*, which, in some cases, has proved positively hurtful to plant-life.

Jamieson (*Chemical News*, vol. lii. p. 287) has shown that in certain cases potassium *chloride* acts as a "plant-poison."

(3) Vegetable Ashes.

As a general rule, the ashes of *wood* contain from 5 to 15 per cent. of potash.

(4) Fish Potash Guano.

When the flesh and bones of the cod and herring are dried, then ground to a powder and mixed with kainit or carnallite, the mixture constitutes what is known in the manure market as "fish potash guano."

The best fish potash guano is made at Jensen's works in the Lofoden Islands of Norway. These manures contain 15 per cent. of sulphate of potash, 7 per cent. of nitrogen reckoned as ammonia, about 10 per cent. of magnesia, and from 8 to 20 per cent. of phosphates (insoluble).

Another manure, under the name of "graxe," is manufactured by Jensen & Co. "Graxe" contains 5½ per cent. of nitrogen reckoned as ammonia, 8 per cent. of potash, 11 per cent. of insoluble phosphates; and is the residue after the extraction of the oil from the cod's liver *plus* a certain percentage of potash salts added during the manufacture of the manure.

Fish potash guano is recommended in the proportion of 5 cwts. per acre for cereals, legumes, and root crops. It should be sown broadcast, and then harrowed into the soil *before* sowing the seed.

From 2½ to 4 cwts. of fish potash guano should be sown broadcast in the early spring or autumn for grass lands.

Fish potash guano is also a good manure for potatoes, cabbages, mustard, and hops, in the proportion of 5 to 7 cwts. per acre.

"There are other 'fish guanos' in the market which *do not contain potash*. They consist of the fish refuse from the large curing factories, reduced to a fine dry meal, and in good condition for agricultural purposes." They contain about 9 per cent. of nitrogen reckoned as ammonia, and from 13 to 16 per cent. of phosphoric acid reckoned as tricalcium phosphate (insoluble).

There is little doubt that fish manures (either with or without the addition of potash salts) are of high agricultural value.

The best time to apply potash salts, especially kainit, is either in the autumn or early spring. Potash manures (as a general rule) should be sown broadcast, and then ploughed or harrowed into the soil.

For *leguminous* plants growing in an ordinary pasture, Sir J. B. Lawes recommends the use of lime in addition to potash. If the land be "limed," a smaller quantity of potash should be used as manure. "Lime economizes the use of potash, and appears to be, to a certain extent, interchangeable with it."

CHAPTER IX.

ARTIFICIAL MANURES (*continued*).

AMONG the "artificial" fertilizers may be enumerated lime, gypsum, salt, etc., the properties and uses of which as manure now claim attention.

(1) LIME.

The use of lime as a manure dates (most likely) from the time of the Romans, but it was limited to manuring fruit-trees.

Lime is a constituent of all plants; its function is connected with the building up of the tissues, and the formation of cell-walls. It is one of the *twelve* "primary" constituents found in plants. These twelve constituents are: water (hydrogen + oxygen), carbon, nitrogen, phosphoric acid, potash, lime, iron oxide, magnesia, sulphuric acid, silica, soda, and chlorine.

The question may be asked: "Are all these constituents of plants indispensable, or not?" Not every one is really required for the life of plants. The last two (viz., soda[1] and chlorine) are not necessary for the production of the majority of farm crops; but the remaining ten constituents must be present in all soils, for "they are absolutely necessary for the growth of plants." Among these ten *vital* constituents of plants, *lime* plays no mean part.

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[1] Possibly *red clover* is benefited by manures containing *soda*.

Lime is not only a direct plant-food, but is one of the most variously effective of manures, and should therefore be studied from many points of view.

(*a*) Lime acts upon the various ingredients contained in soils. It makes those that are inert, assimilable plant-foods, and destroys the bad qualities of the ingredients that are prejudicial to farm crops. Hence it gives fertility to boggy, peaty, or organic soils, by neutralizing the injurious organic acids present in such soils. Therefore, lime is the antidote for "sour" lands, which produce a harsh and coarse herbage of little value as food.

(*b*) Lime, by decomposing organic matter, hastens the process of nitrification.

(*c*) Lime has the power of liberating *soluble* potash from *insoluble* compounds present in soils.

(*d*) Lime improves the *physical* nature of the soil, and has a tendency to promote healthy growth in plants.

(*e*) In the working of clay lands, lime is very valuable. Besides converting insoluble compounds into soluble ones, it renders such lands more friable, and therefore facilitates ploughing.

(*f*) It has also beneficial effects upon sandy soils ot a light nature. It renders them less porous, therefore better able to resist the parching action of the sun's heat during a dry hot summer. Lime also helps to retain moisture in light sandy soils.

(*g*) The *judicious* admixture of lime to most soils is of the utmost importance in any system of husbandry.

(*h*) Lime has proved an excellent "specific" for the turnip disease ("finger-and-toe"), especially for those crops growing on *non*-calcareous soils.

There are "two kinds of lime" at the farmer's disposal,

quicklime and carbonate of lime. As a general rule, on heavy soils and those rich in organic matter, quicklime should be used. For light soils and those poor in organic matter, carbonate of lime should form the dressing.

Both kinds of lime should be harrowed into the land.

"The best and most economical method of treating quicklime is to take a water-cart round, and water the lime heaps *as soon as* they have been placed upon the land. After this slaking, the heaps should be protected from the air by a covering of earth, and left covered until they are spread over the land."

The quantity of lime to apply is from 1 to 2 tons per acre every six or eight years. The application should be made some time before that of other manures.

Lime should never be mixed with sulphate of ammonia, or similar compounds of ammonia.

Wheat, barley (especially for malting), grasses, turnips, beans, peas, clover, potatoes, and vetches, are all benefited by dressings of lime.

The autumn and early winter are the most favourable times of the year for manuring the land with lime.

(2) Gas-lime.

Lime is used in the purification of coal-gas. The residue after the purification is known as gas-lime. It is essentially a mixture of calcium hydrate (slaked lime) and calcium carbonate, together with sulphite and sulphide of lime. The two latter compounds alone are poisonous to plant-life; but they are both converted into gypsum or sulphate of lime (a plant-food) by exposing the gas-lime to the action of the atmosphere.

Gas-lime is best applied in the autumn, at the rate of 2 to 5 tons per acre. This manure has much less agricul-

tural value than either quicklime or carbonate of lime (chalk or limestone).

(3) Gypsum.

Gypsum, sulphate of lime, or plaster of Paris, contains in its hydrated state 32·56 per cent. of lime, 46·51 per cent. of sulphuric acid, and 20·93 per cent. of water.

Gypsum is largely used as a manure for the soils of America, France, and Germany. It is also used to a limited extent in this country as an ingredient in certain "mixed" or "special" manures. It is also an ingredient in ordinary superphosphate of lime.

Mustard, turnip, grass, clover, and potato crops are benefited by dressings of gypsum, if the soil is poor in lime and sulphates.

Gypsum is a direct and indirect plant-food. (*a*) It aids in the formation of the albuminoids contained in plants. (*b*) It absorbs and "fixes" ammonia in the land. (*c*) It liberates potash from certain *insoluble* compouuds of the soil.

(4) Sodium Chloride or Salt.

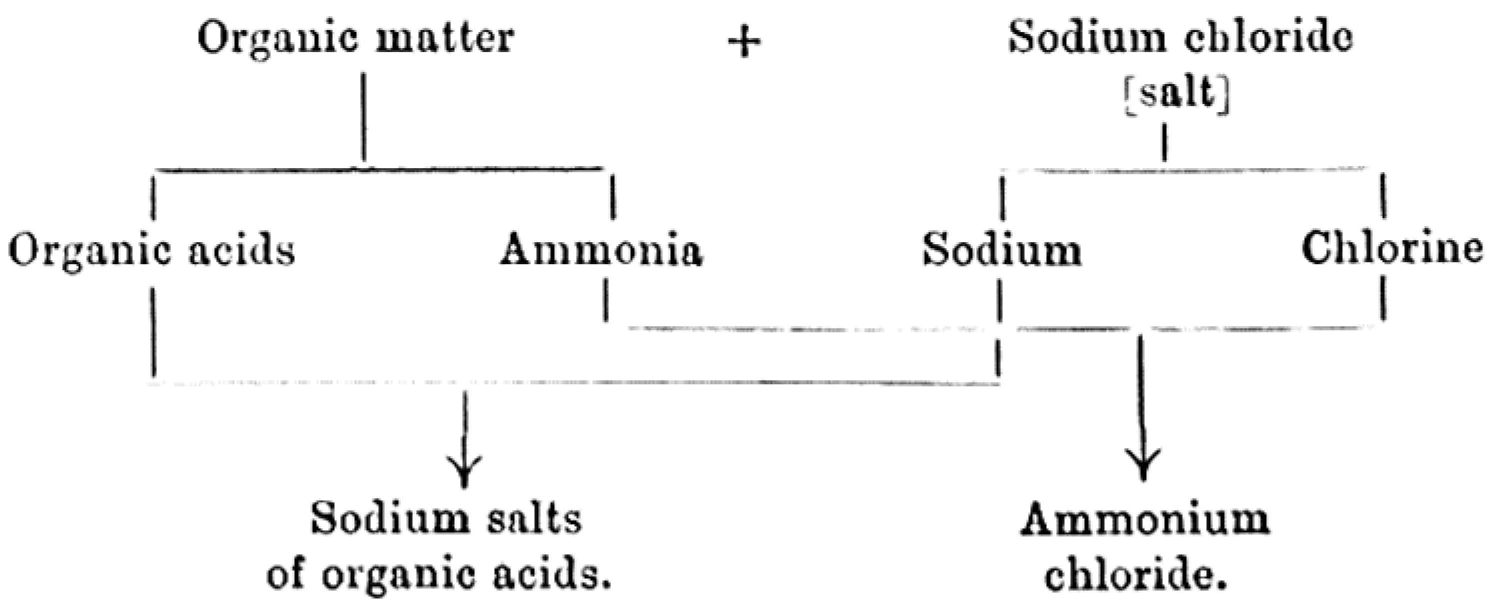
Like lime, salt has been used as a manure from very ancient times.

The action of salt upon plant-life is little understood. There is little doubt that it acts chemically and mechanically upon the land, producing various changes therein, which are beneficial to farm crops.

Salt destroys weeds, noxious insects, snails, and slugs. It retains moisture in dry sandy soils. It checks an abnormal growth of straw, which it strengthens; consequently the crop is better able to resist the attacks of parasitic fungi.

Salt hastens the decomposition of organic matter, at the same time "fixing" the ammonia by converting it into ammonium chloride.

We may *roughly* represent the decomposition, etc., of organic matter and salt by the following diagram:—



On grass lands salt is better used as a compost with organic matter. In this form (a compost) it should be applied at the rate of 4 or 5 cwts. per acre.

Swedes, cabbages, mangel-wurzels, and wheat crops are all benefited when the land is occasionally dressed with salt.

Salt eradicates "couch" on lands infested therewith; and it is useful for mixing with dung, peat, vegetable matters, guano, nitrate of soda, and other manures. These mixtures will be alluded to in Chapter XI.

(5) Sodium Sulphate.

Sodium sulphate, Glauber's salts, or salt-cake, is a manure generally used for cereal and leguminous crops. It is much used as a constituent in "special" manures for clover, corn, bean, and potato crops growing upon light soils.

It should be applied at the rate of $1\frac{1}{2}$ to 2 cwts. per acre.

Sodium sulphate is easily mixed with nitrate of soda, phosphates, and other manures. It supplies sulphur (in the form of sulphuric acid) to the land.

(6) Magnesium Sulphate.

Magnesium sulphate, Epsom salts, or sulphate of magnesia, is used as an ingredient in certain "special" manures.

It forms an excellent top-dressing for all soils growing sugar-canes.

Lawes and Gilbert have used magnesium sulphate in their "mixed" manures for oats with great success.

It is also a good manure for clover and potatoes as well as corn crops.

If a soil, on analysis, shows 0·1 per cent. or less of magnesia, there is every reason to believe that a dressing of magnesium sulphate would prove beneficial.

If lime (as already stated) aids in the formation of plant-tissues, etc., magnesia, like potash, assists in forming starch. The presence of magnesia in soils is necessary for the conservation of their fertility.

CHAPTER X.

ARTIFICIAL MANURES (*continued*).

THE author, in his chemical, agricultural, and microscopic studies of plant-life, having discovered that salts of iron (*in small quantities*) play an important part in the healthy development and growth of plants, devotes this chapter to a short account of the use of iron sulphate as a manure and its value on certain soils. Fuller details of his researches on this subject will be found in his "Treatise on Manures."

(1) IRON SULPHATE.

Iron sulphate, green vitriol, or ferrous sulphate ($FeSO_4$), is a crystallized substance of a grass-green colour. It is manufactured in thousands of tons every year, and is largely used in various manufacturing industries.

Iron sulphate, like nitrate of soda and ammonium sulphate, is *soluble* in water, and when used as a manure should be applied (as a general rule) as a top-dressing. "The first experiments to test the value of *iron* were made in 1846, by Prince Salm-Hortsmar, upon oats, these experiments proving that it was indispensable to the healthy growth of this plant, without it the leaves being pale, sickly, and almost colourless, and the stem and '*head*' thin and poor. From this date various scientific cultivators recognised the value of iron in promoting the healthy growth of plants. Knop, in 1859, experimenting

upon liquids the most favourable to plant growth recognised the necessity of adding phosphate of iron, or of sprinkling the roots of plants upon which he operated, with this salt, and from his experiments drew the conclusion that these four bases—lime, potash, magnesia, and iron oxide—were indispensable to plants.

"In 1860, Dr. Sachs, in his work on the part which mineral substances play in the growth of plants, says:—'Iron is indispensable to the development of the green matter (chlorophyll) in leaves.' Plants grown in solutions deprived of iron are colourless."[1] We need not here remind farmers of the important part played by *chlorophyll* in the physiology of all the higher plants, as details have already been given on this subject.

Many of the older experiments with iron sulphate as a manure, performed in France and in this country, proved failures, the reason being that the experimenters used an *excess* of the salt. A small quantity of iron sulphate (from ½ to 1 cwt. per acre) is most beneficial, a large quantity is injurious. Although most of the soils of this country contain a certain amount of iron, it is not always in the most suitable form for root-absorption—and it may be that many farm crops (which only live a few months) suffer from a want of "this life-giving substance." The weak acids secreted by the rootlets are most likely insufficient to obtain the requisite amount of iron from the soil for a healthy growth. Many soils, too, do not contain a sufficient supply of iron compounds for the proper growth of the crops under cultivation (see later in this chapter). If cultivated lands are not provided with phosphates, nitrogen, iron, and other substances

[1] S. T. Griffiths, *The Tamworth Herald*, August 11th, 1888.

necessary for plant-life, can farmers wonder that their crops are failures or become diseased? The composition of the soil and the exact requirements of each crop cultivated must be known before the farmer can work with the least expenditure of money, and with the greatest success.

(a) *Iron Sulphate for Meadow Hay.*

In 1886 the author grew meadow hay with and without top-dressings of iron sulphate.

"Two plots of land (of similar chemical and mechanical composition) were chosen of the same size (an acre each). Each plot was exposed to the same atmospheric influences. Both were manured, first of all, with farmyard manure (the same quantity on each plot). Upon each plot of land 16 lbs. of ordinary grass seeds were sown per acre. After the grass had made its appearance above ground, ½ cwt. of iron sulphate was used on one of the plots as a top-dressing. The other plot did not receive any iron sulphate or other artificial manure."

At the harvest, the acre of land manured *with* iron sulphate yielded 3 tons 2 cwts. of hay, and the land *not* top-dressed with iron sulphate gave only 1½ tons of hay. The hay from the "manured" plot was of far better quality than that from the unmanured plot.

During the years 1887 and 1888, *important* experiments were made in France by M. Marguerite-Delacharlonny and others[1] on the use of iron sulphate for grass (producing meadow hay) growing on soils of *various* compositions.

[1] The results were published in the *Journal de l'Agriculture* (Paris) for November 17th, 1888, pp. 787–790.

The compositions of the French soils were as follows —

	No. I.	No. II.	No. III.	No. IV.	No. V.
Iron oxide	2·929	2·531	1·340	3·573	4·321
Phosphoric acid	0·118	0·142	0·093	0·106	0·169
Potash	0·172	0·172	0·071	0·162	0·152
Lime	1·029	2·263	0·836	1·125	2·373
Magnesia	0·040	0·030	0·020	0·090	0·045
Soda	0·015	0·036	0·031	0·024	0·032
Nitrogen	0·354	0·280	0·401	0·382	0·354

The above figures represent percentages of the ingredients mentioned.

In 1887, these soils gave, *with* and *without* iron sulphate, the following results per hectare (2·47 acres):—

Plots.	Yield of Hay when grown *without* Iron Sulphate.	Yield of Hay when grown *with* Iron Sulphate.	Quantity of Iron Sulphate used per Hectare.[1]	Difference.	
				Total.	Per cent.
	Kilograms.[1]	Kilograms.	Kilograms.	Kilograms.	
No. I.	2,000	4,788	65	2,788	139·4
„ II.	1,838	3,052	350	1,314	71·5
„ III.	1,803	2,864	200	1,061	57·8
„ IV.	4,346	4,603	200	257	5·9
„ V.	3,614	3,500	125	114	—

Similar results were obtained during the season of 1888.

These French experiments prove—

(1) That iron sulphate is a most important manure for grass lands, greatly increasing the yield.

(2) If the soil (on analysis) contains already 4 per cent. or *more* of iron oxide, the farmer need not add the iron manure; for then the soil has a sufficient supply for the growing crop.

[1] 1 hectare = 2·47 acres. 1 kilogram = 2·2 lbs. (Avoir.).

(3) All soils containing less than 4 per cent. of iron oxide are benefited by dressings of iron sulphate.

(4) With a soil (No. I.) containing 2·929 per cent. of iron oxide and dressed with 65 kilogrammes of iron sulphate per hectare, the *profit* (net) on an increase of 2,788 kilogrammes of hay was 191 francs 10 centimes (*i.e.*, over £7).

The author has shown (*Journal Chemical Society*, 1886, p. 114) that iron sulphate destroys *moss* infesting pasture lands. His experiments have since been confirmed by those of Messrs. Macqueen, Edgson, and others in this country, and Messrs. Delacharlonny, Lambin, Néron, and others in France.

M. Delacharlonny says in the *Journal de l'Agriculture* (Oct. 27th, 1888): "Le sulfate de fer appliqué judicieusement détruit complètement la mousse des prairies et donne à l'herbe, après l'avoir débarrassée de son parasite, un développement remarquable." Then again, in the same journal, he quotes from a letter of "M. P——, juge au tribunal de la Seine, propriétaire à Montalivet, par la Ferté-Gaucher (Seine-et-Marne)," these words: "L'emploi du sulfate de fer dans les conditions que vous m'avez indiquées a produit sur une prairie l'effet que vous annonciez. Les mousses ont été détruites. Je crois pouvoir affirmer que le sulfate de fer employé avec prudence peut être appelé *à rendre de réels services pour la destruction des mousses et la régénération des prairies.*"

(b) *Iron Sulphate for Bean Crops.*

During the years 1883, 1884, and 1886, the author grew bean crops with and without iron sulphate manure.

The soil used in these experiments was a clayey loam containing 3·9 per cent. of iron oxide.

The following results were obtained at the harvest in each case:—

	1883 Crops.		1884 Crops.		1886 Crops.	
	Grown *with* Iron Sulphate.	Grown *without* Iron Sulphate.	Grown *with* Iron Sulphate.	Grown *without* Iron Sulphate.	Grown *with* Iron Sulphate.	Grown *without* Iron Sulphate.
Total weight of crops when dry (grain + straw) per acre . . .	lbs. 5,882	lbs. 4,487	lbs. 5,325	lbs. 4,105	lbs. 5,929	lbs. 4,726
Yield of grain in bushels (dry) .	56	35	44	28	50	30

"On the average of three years' crops there is a gain of 19 bushels of beans per acre by using iron sulphate as a manure," at the rate of ½ cwt. per acre.

Not only was the yield increased (where iron sulphate was used), but the quality of the grain and straw was likewise enhanced.

(c) *Iron Sulphate for Sugar-beets.*

During the year 1887 an extensive series of experiments were made at certain well-known agricultural stations in France on the growth of beetroots by using iron sulphate as a manure.[1]

One of these series was conducted by Professor A. Müntz (l'Institut National Agronomique, Paris) on La Ferme Nationale de Vincennes. The soil contained 3·4 per cent. of iron oxide. A second series of experiments was performed by M. Porion (the *confrère* of M. Dehé-

[1] Published in *La Sucrerie Indigène et Coloniale*, vol. xxxi. [1888], pp. 571–576.

rain) at Wardrecques (Nord). The Wardrecques soil is a calcareous clay containing 6·7 per cent. of iron oxide.

A third series was performed at Chailvet (Aisne) by M. Delacharlonny, who found that the soil contained 1·4 per cent. of iron oxide.

A fourth series was performed at Bellevue by M. Paul Genay.

The conclusions drawn from these experiments are the following:—

(1) Iron sulphate is a good manure for beetroots. "The *increase* in the crops varied from 5 to 30 per cent., according to circumstances."

(2) "65 kilogrammes per hectare is a convenient quantity if used in solution (*i.e.*, dissolved in water), but rather too small if used in the powdered condition. The quantity applied should vary according to the nature of the soil."

(3) "The quantity of beetroots is greatly improved by the use of iron sulphate. The sugar increases as the weight of the crop increases, and the greatest weight is obtained by using iron sulphate."

(d) *Iron Sulphate for Turnip Crops.*

During the year 1884 the author grew turnip crops with and without iron sulphate. The plot of land manured with $\frac{1}{2}$-cwt. of iron sulphate per acre yielded $16\frac{1}{2}$ tons, while the plot of land in its normal state gave only 13 tons of turnip roots per acre. Both plots of land were previously manured with the same quantity of dung, and the composition of the two soils was almost identical. It is evident that iron sulphate is a good manure for turnips.

(e) *Iron Sulphate for Mangel-wurzels.*

In 1886 the author grew mangel-wurzels ("Orange Globe" variety) with and without dressings of iron sulphate.

Two plots of land (each an acre) were chosen for the experiments. Each plot received a dressing of 10 tons of good farmyard manure in the winter. "In the spring (April, 1886) the following mixture was applied broadcast on *each* plot of land: 1 cwt. of kainit, 1 cwt. of nitrate of soda, 4 cwts. of superphosphate of lime, and 2 cwts. of common salt."

On each plot 5 lbs. of seeds were sown by hand-dibbling, "and when the young plants were ready, they were 'singled,' the distance between plant and plant being about 12 inches. A month after 'singling,' a top-dressing of 1 cwt. of nitrate of soda and ½-cwt. of iron sulphate was applied to plot A, whilst 1 cwt. of nitrate of soda only was used on plot B." At the harvest in October, plot A yielded 32 tons of roots, and plot B only 26 tons.

The quality of the produce from plot A was much superior to that of plot B. Therefore, on some soils, iron sulphate is a good manure for mangel-wurzels.

(f) *Iron Sulphate for Potatoes.*

During the years 1885 and 1886 potato crops were grown with and without dressings of iron sulphate.

Three plots of well-drained land were chosen for the experiments. Each plot was an acre in extent, and the soil of good quality. Plot A was not treated with any manure. Plot B was dressed with a mixture consisting of 1 cwt. of kainit, 1 cwt. of nitrate of soda, ½-cwt. of iron sulphate, and 2 cwts. of superphosphate of lime. Plot C

was manured with the above mixture *minus* the $\frac{1}{2}$-cwt. of iron sulphate.

At the harvest, plot A yielded 3 tons of tubers, plot B yielded $8\frac{1}{2}$ tons, and plot C gave $6\frac{1}{2}$ tons of tubers.

It is evident that iron sulphate is a valuable manure for potato crops, greatly increasing the yield. Its action is apparently of an indirect as well as a direct nature. In 1886 experiments were undertaken to ascertain the comparative manurial values of iron sulphate and kainit for potatoes.

"Two plots of land (each an acre) were manured with 15 tons of farmyard manure, in the autumn, and upon each plot was sown 6 cwts. of potato tubers." When the plants were fairly above ground, plot A received a top-dressing of $\frac{1}{2}$-cwt. of iron sulphate, and plot B 2 cwts. of kainit (containing 16% potash). At the harvest, plot A yielded 9 tons of tubers, and plot B only 6 tons.

Therefore iron sulphate is a valuable addition to the list of fertilizers for "potato-soils."

The above results, which were originally published in the *Journal of the Chemical Society*, have been confirmed by Messrs. Barlow, Brinkworth & Sons, Wright, and Dr. Munro in this country (see the author's "Treatise on Manures").

During the year 1887, M. Delacharlonny (*Journal de l'Agriculture*, Nov. 17th, 1888, pp. 788–789) conducted a series of interesting experiments with iron sulphate in conjunction with other fertilizers on potato crops. The soil of Ursel (Aisne) contains 1·825 per cent. of iron oxide, 0·083 per cent. of phosphoric acid, 0·308 of potash, 0·35 of lime, and 0·123 per cent. of nitrogen.

The land was divided into 10 plots. The manures used, and the yield per hectare (2·47 acres) are given in the following table :—

DELACHARLONNY'S POTATO CROPS.

Plots.	Manures used per hectare.	Yield of tubers per hectare.	Increase on the average yield of the two unmanured plots.	Net profits.
No. I.	Unmanured	2,000 Kilograms.	—	—
,, II.	Unmanured	3,100 ,,	—	—
,, III.	65 Kilograms. of iron sulphate	4,100 ,,	1,550 Kilograms.[1]	fr. 90·90
,, IV.	65 ,, ,, ,, ,,	4,200 ,,	1,650 ,,	,, 128·10
,, V.	250 ,, ,, ,, ,,	5,300 ,,	2,750 ,,	,, 205·0
,, VI.	2,000 ,, ,, old plaster[1]	6,700 ,,	4,150 ,,	—
,, VII.	x ,, ,, limestone	7,300 ,,	4,750 ,,	,, 356·10 (VII. and VIII.)
,, VIII.	10,000 ,, ,, limestone 65 ,, ,, iron sulphate	7,300 ,,	4,750 ,,	
,, IX.	2,000 ,, ,, plaster 65 ,, ,, iron sulphate	7,300 ,,	4,750 ,,	,, 326·10
,, X.	2,000 ,, ,, plaster 250 ,, ,, iron sulphate	8,000 ,,	5,450 ,,	,, 371·0

[1] Old plaster consists of the carbonate and sulphate of lime.
1 kilogram. = 2·2 lbs. (Avoir.).

The soil used in these experiments was poor in iron oxide and *lime*. The above results show that the manurial value of iron sulphate is greatly increased by the addition of calcareous compounds to the land, if it is poor in lime. In any case there is a decided profit by using a dressing of iron sulphate for potato crops.

In 1888 Mr. J. J. Barlow, Oak Lane Farm, Whitefield, Manchester, grew (for a second season) potato crops with and without iron sulphate.

The soil was a well-drained, light, sandy loam, with a trace of peat. A field of 8 acres was manured with a mixture of farmyard manure and "night-soil." The field was then planted with "champion" potatoes, in drills 27 inches wide. When the plants were about 6 inches above ground, two adjacent plots ($\frac{1}{8}$-acre each) were measured off, each containing eight drills or furrows.

Plot A received a top-dressing of iron sulphate, previously mixed with its own weight of dry sand (to obtain a more even distribution) and sown broadcast on two drills at a time, at the rate of $\frac{3}{4}$-cwt. per acre. B was left normal. At the harvest the following results were obtained :—

	Tons per acre.	Loads (1 load = 252 lbs.).	Price obtained per acre. £	s.	d.	
Plot A, manured with iron sulphate	4·90 1·86	43$\frac{1}{2}$ 7$\frac{3}{4}$	15 1	4 3	6 3	(large table potatoes) (small "chat" potatoes)
Total	6·76	51$\frac{1}{4}$	16	7	9	
Plot B, not manured with iron sulphate	3·73 1·29	33 11$\frac{1}{2}$	11 1	11 14	0 6	(large table potatoes) (small "chat" potatoes)
Total	5·02	44$\frac{1}{2}$	13	5	6	
Increase in weight and value per acre	0·74	6$\frac{3}{4}$	3	2	3	

The potatoes grown with iron sulphate were "very clean and sound, and of splendid flavour."

(g) *Iron Sulphate for Lucerne.*

Lucerne (*Medicago sativa*) belongs to the *Leguminosæ*, or the same order of which clover, beans, peas, and vetches are important members.

In 1888, M. Delacharlonny (*Journal de l'Agriculture*, Nov. 17th, 1888, p. 788) grew crops of lucerne with and without dressings of iron sulphate. The soil on which the experiments were made contained :—

Iron oxide	4·320 per cent.
Phosphoric acid . . .	0·500 ,,
Potash	0·339 ,,
Lime	0·680 ,,
Sulphuric acid . . .	0·116 ,,
Nitrogen	0·112 ,,
Magnesia	0·180 ,,

At the harvest, the crop grown *with* iron sulphate yielded 2,932 kilogrammes, while the other crop yielded only 2,344 kilogrammes per hectare, showing an *increase* of 588 kilogrammes (or an increase of 25 per cent.) by using iron sulphate.

Although the soil contained over 4 per cent. of iron oxide, the produce was greater from the plot manured with iron sulphate. M. Delacharlonny, however, remarks in his paper (*loc. cit.*), "this soil was not completely homogeneous."

Lucerne is highly esteemed in France, and on the Continent generally, as a forage plant. It is extensively grown in the west and south of France, and is better adapted for warmer climates than Great Britain. It grows well in the south of England in dry, deep soils.

(h) *Iron Sulphate versus Parasitic Diseases.*

Several authors have written upon the value of iron sulphate as an agent for destroying the microscopic fungi which are instrumental in producing certain diseases of farm and garden crops.

The fungi which infest farm crops are, as a rule, all built upon the same plan; viz., they are made up of protoplasm ("the basis of life") and hyphal filaments, which contain an external wall of a peculiar kind of cellulose ("micro-parasitic cellulose") differing from the cellulose of the higher plants. This micro-parasitic cellulose is chemically acted upon by iron sulphate, but not the cellulose of farm crops, hence the reason that the fungoid growths are destroyed by this reagent.

The author has proved that iron sulphate destroys *Peronospora infestans* (the potato disease fungus), the wheat mildew and its spores in both stages of their life-history (*Chemical News*, vol. liii. p. 255; *Journal Chemical Society*, 1886, p. 119), and the fungus which causes tubercular swellings upon the roots of *Vicia faba* (field bean).[1]

There is also a fungus which produces nodular outgrowths upon the roots of the cucumber (*Cucumis sativa*). The author made a complete study of the life-history of this fungus, which he subsequently called *Ustilago cucumis* ("Proceedings Royal Society, Edinburgh," vol. xv. p. 403).

This cucumber-root fungus belongs to the *Ustilagineæ*, and like the "smuts," which are members of the same order, consists of celluloid hyphal filaments containing

[1] *Chemical News*, vol. lvi. p. 84.

protoplasm. Fig. 11 illustrates a microscopical section of a cucumber root infested with this fungus. The hyphæ pass, cell by cell, through the cortex of the rootlet. The fungus obtains its nourishment from the protoplasm of

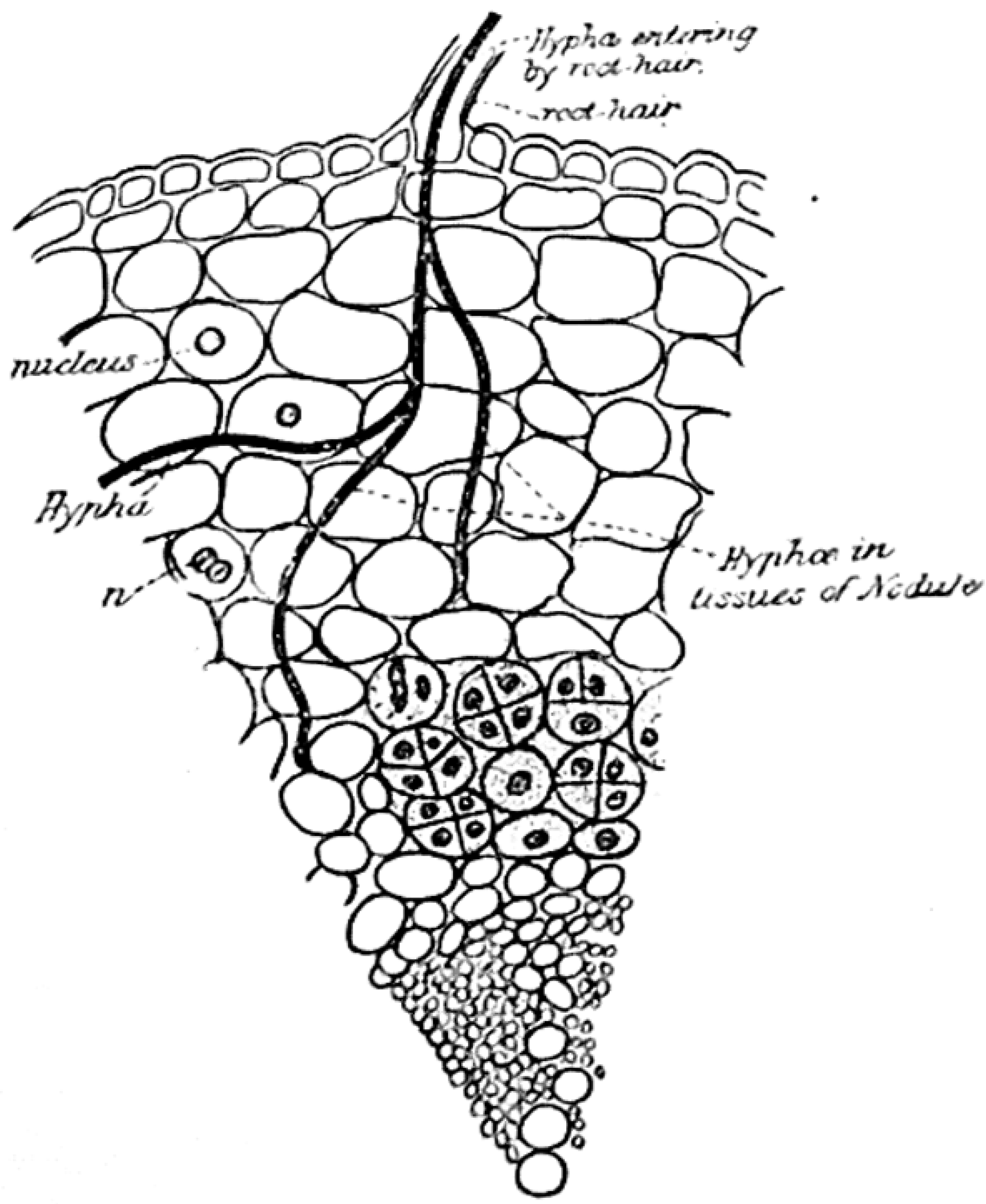


FIG. 11.—TRANSVERSE SECTION OF A YOUNG ROOTLET AND SMALL NODULE (× 713 diameters).

the cells of its host, thereby destroying or greatly impairing its vitality.

The spores of *Ustilago cucumis*, which are extremely

small, are found in the soils (where cucumbers have grown) "in the autumn and early winter, having been liberated by the rotting of the root-nodules. These spores retain their vitality for months, and are capable of attacking the new seedlings planted in such soils. The spores are easily disseminated by such agencies as air, soils, and streams."

The cucumber-root fungus is completely destroyed by iron sulphate.

Iron sulphate also destroys *Claviceps purpurea*, the ergot of rye and other cereals, as well as of *mature* grasses.

Farmers should take the precaution to cut grass when in the bloom, rather than in the seeding state; it will then be impossible for ergot to appear.

Not a few cases have occurred, especially in Ireland and the States of America, "where hay was found to contain an eighth of its weight of ergot." This fodder caused abortion and ergotism[1] in cows. As a general rule, "ergot does not cause abortion, except the fœtus has reached a considerable size in the uterus."

From these remarks it is evident that iron sulphate, dissolved in water, forms an excellent "steep" for destroying the germs of diseases found at certain times on seeds.

Top-dressing the land with iron sulphate is also a means of destroying fungoid germs which may be present in any cultivated soil.

For further details on the antiseptic properties of iron sulphate, the author refers his readers to his "Treatise on Manures."

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[1] Producing a kind of mortification called "dry gangrene."

(i) *Which is the Active Ingredient in Iron Sulphate?*

Iron sulphate is composed of iron, sulphur, and oxygen. The active manurial ingredient in this compound has been given by some to the iron, and by others to sulphur.

We believe that both ingredients are important plant-foods, and that *iron* sulphate is one of the, if not the, most important sulphate used in scientific agriculture. Professor A. Müntz (L'Institut National Agronomique, Paris)[1] says: "With *any* sulphate[2] there is an increase of 13·54 per cent. (in the growth of crops), but with *iron* sulphate the increase is 30·2 per cent." M. Müntz also obtained an *increase* of 9·6 per cent. of chlorophyll in those crops grown with *iron* sulphate.

The analysis of the ashes of the author's crops gave the following percentages of iron oxide, phosphoric acid, potash, and sulphuric acid respectively in those crops grown with and without iron sulphate:—

---

[1] *La Sucrerie Indigène et Coloniale*, vol. xxxi. p. 572.
[2] Ammonium sulphate is not included.

Season.	Crops.	A. Yield per acre when grown *with* Iron Sulphate.	A. Iron Oxide in Ashes.	A. Phosphoric Acid in Ashes.	A. Potash in Ashes.	A. Sulphuric Acid in Ashes.	B. Yield per acre when grown *without* Iron Sulphate.	B. Iron Oxide in Ashes.	B. Phosphoric Acid in Ashes.	B. Potash in Ashes.	B. Sulphuric Acid in Ashes.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1883	Beans (dry)	56 bushels	4·2	41·8	18·3	1·02	36 bushels	1·0	37·9	20·7	1·40
1884	Beans (dry)	44 bushels	4·9	40·8	17·9	1·16	28 bushels	1·0	37·8	20·9	1·39
,,	Turnips (roots)	16½ tons	1·2	17·9	43·8	5·01	13 tons	0·3	16·4	50·1	6·95
1885	Potatoes (tubers)	8½ tons	7·0	17·9	52·9	3·34	3 tons	5·1	15·6	53·8	4·00
1886	Meadow hay	3 tons 2 cwts.	4·4	7·6	18·2	3·54	1½ tons	1·2	5·3	18·3	2·89
,,	Mangels	32 tons	4·2	12·2	43·9	2·92	26 tons	2·4	9·9	46·6	1·02
,,	Beans (dry)	50 bushels	4·8	40·6	—	—	30 bushels	1·09	37·4	—	—
,,	Potatoes (tubers)	9 tons	7·2	18·3	51·0	—	6 tons	5·2	16·5	53·5	—
1885	Grass	—	2·4	7·2	23·1	7·43	—	0·4	5·5	24·9	8·46
1882	Cabbages	—	12·2	16·2	31·6	7·64	—	8·3	12·9	33·9	8·61

It will be noticed from the above results, (1) that an increase of *iron* oxide in the ashes coincides with an increase in the yield of those crops grown with iron sulphate. (2) As the iron oxide increases, phosphoric acid also increases, showing that iron sulphate is an *indirect* as well as a direct plant-food.[1] (3) In the ashes of the crops grown *with* iron sulphate, the percentages of potash and sulphuric acid (as a rule) decrease as the iron oxide increases.

Judging from these data, if reliable, the *iron*, as an ingredient in iron sulphate, is certainly a plant-food, and is therefore an important element in the growth and development of farm crops.

(j) *Action of Iron Sulphate on Plants.*

(1) Iron sulphate "increases the percentage of soluble carbohydrates and albuminoids in various crops, and thus enhances their value as feeding stuffs." (2) "The sulphur of iron sulphate most likely acts as a food for the protoplasm of vegetable cells, and the iron for the chlorophyll." (3) Iron sulphate possibly aids the absorption of phosphoric acid and nitrogen. Therefore it is an *indirect* as well as a direct plant-food. (4) It destroys parasitic fungoid diseases in farm and garden crops.

(k) *Action of Iron Sulphate on Soils.*

(1) Iron sulphate retains ammonia and phosphoric acid in soils. (2) Most likely iron sulphate hastens the decomposition of organic matter. That is, it acts chemically upon the inert constituents of the soil, convert-

[1] These results have been confirmed by MM. Müntz, Porion, and Delacharlonny, in France.

ing them into *soluble* plant-foods. (3) If a soil contains from 5 to 6 per cent. or more of iron oxide (Fe_2O_3), iron sulphate (as far as the iron is concerned) appears to have little or no beneficial action. In such cases, which are rare, the soil has already an abundance of iron. The farmer must know the composition of his soils before he can manure them with economy. (4) Iron sulphate destroys moss in pasture lands.

(1) *Application of Iron Sulphate to the Land.*

(1) Iron sulphate may be sown broadcast by hand, as a top-dressing, when the crops are a few inches above ground; or mixed with 2 to 10 times its weight of sand or soil and distributed by hand, or by the manure distributor (Fig. 9; see Chapter VI.). Iron sulphate may also be used in solution and distributed by means of a water-cart. (2) "It is essential for the farmer to bear in mind that from ½-cwt. to 1 cwt. of iron sulphate per acre are the only proportions which give good results with his crops." (3) Iron sulphate must always be used on wet ground.

The selling price of *commercial* iron sulphate is from 35*s*. to 50*s*. per ton; and it can easily be obtained from any wholesale druggist or manufacturer of the article, in either large or small quantities.

CHAPTER XI.

SPECIAL MANURES.

SPECIAL manures are mechanical mixtures of various plant-foods. When carefully compounded, they give to the soil the various ingredients required for each crop grown,—and as a general rule special manures are made to suit *all* or *most* soils.

The manure manufacturer, having to consider the requirements of various crops and soils of a most heterogeneous nature, compounds his special manures with ingredients not required for certain soils and crops. These ingredients have to be paid for by the agriculturist, who thereby purchases materials not required for his particular land.

Surely this is not an economical way of adding manures to cultivated soils. The coming farmer should compound his own "special" or "mixed" manures. Special manures are now sold under such names as "Cereal Manure," "Mangel Manure," "Corn and Grass Manure," etc.; and most manufacturers have their own formulæ or recipes for preparing these manures.

LAWES' special manures contain the following ingredients (percentage) amongst others:—

	Soluble Phosphates.	Insoluble Phosphates.	Soluble and Insoluble Phosphates.	Ammonia.
"Potato Manure" .	—	—	20 to 23	3 to 4
"Turnip Manure" .	22 to 24	6 to 8	28 to 32	1 to 1¼
"Grass Manure" . .	20 to 24	8 to 12	28 to 36	1½
"Mangel Manure" .	—	—	20 to 23	3 to 4
"Cereal Manure . .	—	—	20 to 23	3 to 4
"Corn and Grass Manure"	12 to 15	—	—	7 to 8

The last-named manure is "specially prepared for top-dressing in the spring, and is beneficial upon crops that have suffered from the frost." For wheat it should be applied at the rate of 2 to 2½ cwts. per acre. "For barley, 1½ to 2 cwts. per acre, and harrowed in just when the blade appears above ground."

Messrs. OHLENDORFF prepare a series of special manures suitable for sugar-cane growing in the soils of the West Indian Islands. Amongst these "specials" are the following:—

(1) "*Special Cane Manure*" (*Ohlendorff's*).

Nitrogen = 9 per cent. of ammonia
18 per cent. of soluble } phosphates
4 per cent. of assimilable } phosphates
7 per cent. of sulphate of potash.

(2) "*Early Cane Manure*" (*Ohlendorff's*).

Nitrogen = 5 per cent. of ammonia.
20 per cent. of soluble and assimilable phosphates.
13 per cent. of sulphate of potash.

Most "cane soils" are benefited by top-dressings of magnesium sulphate in addition to nitrogen, potash, and phosphates.

(a) *Special Manures for Clovers and Allied Crops.*

Phosphoric acid and potash are the most important ingredients of "clover manures." All these crops are gross *nitrogen feeders*, but they have the power of gathering up nitrogen from the soil more than any other crop.

A good special manure for clovers is prepared by mixing from—

230 to 280 lbs. of superphosphate (20 per cent.),
140 to 160 lbs. of kainit (24 per cent.),

together. Later in the season, a top-dressing of 168 lbs. of nitrate of soda, in three instalments of 56 lbs. each, should be applied.

(b) *Special Manures for Cereal Crops.*

These crops are benefited by manuring the land with soluble and insoluble phosphates, *nitrogen*, and *potash*. "It is a great mistake to suppose that in most cases an exclusive manuring with phosphoric acid (superphosphates) is the proper thing for cereals." We have already given certain special manures for wheat and similar crops (see Chapter VII.).

M. Ville recommends the following special manure for wheat, without the addition of farmyard dung:—

		£	*s.*	*d.*
Superphosphate of lime . . .	176 lbs. =	0	7	8
Potassium chloride (80 per cent.) .	88 „ =	0	6	5
Ammonium sulphate . . .	171 „ =	1	11	2
Calcium sulphate (gypsum) . .	93 „ =	0	0	8
Per acre	528 „ =	2	5	11

Messrs. Lawes and Gilbert have used the following mixtures (per acre) for wheat, barley, and oats, with the greatest success:—

	Oats.	Wheat.	Barley.
Potassium sulphate . . .	200 lbs.	200 lbs.	200 lbs.
Sodium sulphate	100 „	100 „	100 „
Magnesium sulphate . .	100 „	100 „	100 „
Superphosphates	3 cwts.	3½ cwts.	3½ cwts.
Ammonia salts	400 lbs.	200 lbs.	—
Nitrate of soda	—	—	275 lbs.

As a general rule, seed drilled in requires more nitrate of soda than that sown broadcast.

(c) *Special Manures for Potatoes.*

Liberal manuring is essential for the proper growth and development of potato crops. Potatoes require potash, nitrogen, and phosphates. They are also greatly benefited by dressing the land with the sulphates of iron and magnesia.

The author recommends the following special manure for potato crops:—

			£	s.	d.
Per acre.	1 cwt.	kainit	0	2	0
	1 ,,	nitrate of soda	0	9	10
	½ ,,	iron sulphate	0	1	3
	2 ,,	mineral superphosphate	0	5	0
			0	18	1

By using iron sulphate there is little danger of the crops being attacked by *Peronospora infestans* (the potato disease fungus).[1]

Amongst the special manures for potato crops are the following:—

	I.	II.
Superphosphates	3 cwts.	3 cwts.
Sulphate of ammonia	1 ,,	1 ,,
Kainit	2 ,,	1 ,,
Sodium sulphate	—	1

The quantities stated to be applied per acre.

(d) *Special Manures for Mangels, Turnips, etc.*

The author has used the following mixed manure for

[1] Iron sulphate does *not* act upon the nitric acid of sodium nitrate, which otherwise would cause a loss of nitrogen (see Dr. Devarda's paper in "Chem. Centr." 1888, p. 899).

mangel-wurzels on both heavy and light soils with considerable success:—

		£	s.	d.
3 cwts.	mineral superphosphates (26 to 28 per cent.)	0	7	6
½ ,,	iron sulphate (*commercial*)	0	1	3
1½ ,,	ammonium sulphate (24 per cent.)	0	18	7½
1 ,,	kainit (24 to 26 per cent.)	0	2	0
		1	9	4½

This manure (after mixing) should be distributed

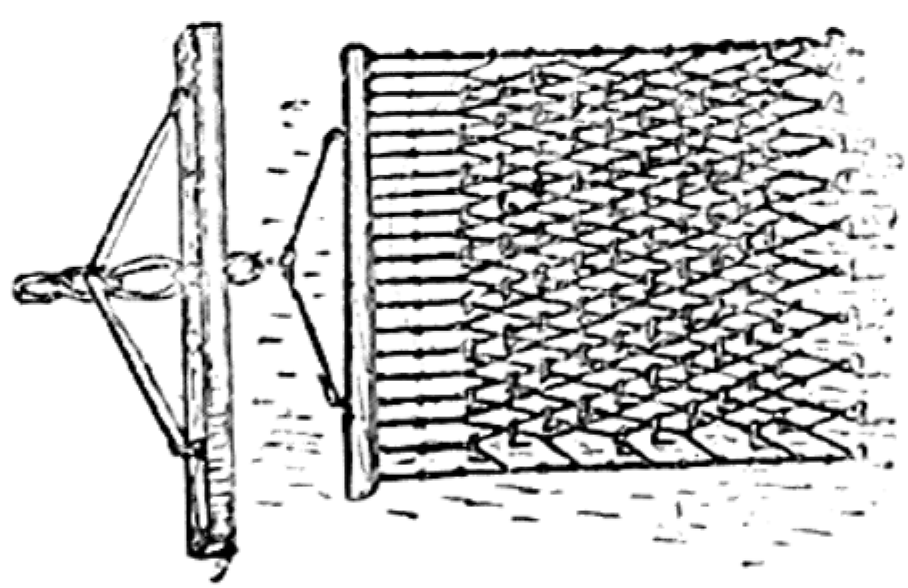

FIG. 12.—STEEL CHAIN HARROW.

broadcast by either hand or machine;[1] and then covered over by means of a chain-harrow (Fig. 12).[2]

The highest and lowest quantities of nitrogen and phosphoric acid used in the preparation of special manures

[1] The above quantities per acre.
[2] Good chain-harrows are made by Vipan and Headly (Leicester).

for *turnips* should be the following, according to circumstances:—

	Highest.	Medium.	Lowest.
Nitrate of soda	465 lbs.	270 lbs.	145 lbs.
Superphosphate (20 per cent.) .	270 ,,	225 ,,	180 ,,

The above quantities should be used per acre according to whether the soil is rich or poor in nitrogen and phosphoric acid.

(e) *Special Manures for Grass Lands.*

Sir J. B. Lawes and Dr. Gilbert have used the following special manures for grass land with good results:—

Per acre.
- 500 lbs. potassium sulphate (kainit).
- 100 ,, sodium sulphate.
- 100 ,, magnesium sulphate.
- $3\frac{1}{2}$ cwts. superphosphate.
- 800 lbs. ammonia salts.
- 400 ,, sodium silicate.

"This manure produced $44\frac{1}{4}$ cwts. of hay (first crop) per acre during the twenty-five seasons of using 'artificials.'"

Grass lands are benefited by top-dressings of iron sulphate at the rate of $\frac{1}{2}$ to 1 cwt. per acre.

(f) *Special Manures for Flax and Hemp.*

These plants should be manured with potash salts, nitrate of soda, and phosphoric acid. The manure applied should vary with the nature of the soil in the following proportions per acre:—

360 to 540 lbs. kainit.
135 to 270 ,, nitrate of soda.
180 to 270 ,, superphosphate (20 per cent.).

According to Dr. Fleischmann ("*Der landwirthschaftlichen Versuchs-Stationen*," 1873), the common salt (about 30 per cent.) present in kainit has "a good effect upon the quantity and quality of these crops."

(g) *Common Salt, an ingredient of certain Special Manures.*

Common agricultural salt, in certain cases, is a valuable addition to special manures, especially for wheat crops. This value does not lie in its properties as a direct plant-food, for in this respect it is undoubtedly low; but on account of its chemical action upon the soil's inert ingredients.

(1) It "fixes" ammonia in most soils. (2) It decomposes carbonate of lime and forms sodium carbonate, which has the power of dissolving silica, and thereby provides wheat, oats, barley, rye, etc., with the latter compound.

The following special manure for *wheat* crops has been recommended on account of its fertilizing action upon a large number of soils:—

Sulphate of ammonia	120 lbs.
Salt	100 ,,
Superphosphates	200 ,,
Nitrate of soda	40 ,,
Insoluble phosphates (ground coprolites)	260 ,,
Sulphate of lime (gypsum)	280 ,,
	1,000 lbs.

The above quantity (after mixing) should be applied per acre.

Salt enters largely into certain composts. The late

Mr. Fleming used a compost of the following ingredients:—

Common salt	$1\frac{1}{2}$ cwt.
Sulphate of magnesia	$1\frac{1}{2}$,,
Sulphate of soda	1 ,,
Quicklime	20 bushels.
Sawdust	40 ,,
Bone-dust	7 ,,
Coal-tar	20 gallons.

These ingredients are made into a heap and allowed to ferment for 3 or 4 weeks.

Salt must not be used too freely, as rain-water often contains a considerable amount of this compound. The late Dr. Madden showed that "at Penicuik, near Edinburgh, the rain that falls contains so much *common salt* as alone to convey 640 lbs. to every acre in a year."

It is to be hoped that the farmer will study the peculiarities of his soils, and the requirements of each crop cultivated. By a series of experiments and observations on the foregoing recommendations, he would be able to prepare his own special manures, and thereby save a considerable sum of money, which is now spent in expensive mixed manures prepared by the manufacturer to suit "*all sorts and conditions*" of soils.

Concluding Remarks.

The author hopes "that the intelligent reader will perceive the foundations of the varied applications to the soil which are everywhere made under the direction of a skilful practice, and of the difficulties which, in many localities, lie in the way of bringing the land into such a state as shall fit it readily to supply all the wants of those

kinds of crops which it is the special object of artificial culture easily and abundantly to raise." (Johnston.)

Science, and especially chemistry, has thrown a considerable amount of light on the art of cultivating the soil and the raising of farm crops. But there are still many problems requiring solution, which no doubt science is destined to solve for the benefit of farmers.

Let farmers shake hands with scientific men, instead of standing aloof, and the art of manuring and cultivating the land would be better understood and more profitably carried out by agriculturists than is the case at the present day.

As already stated, there are many agricultural problems requiring solution, "in regard to which agriculture has a right to say to chemistry, 'There are matters which I hope and expect you will satisfactorily clear up.' But while agriculture has a right to use such language, she has herself preliminary duties to perform. She has no right in one breath to deny the value of chemical theory to agricultural practice, and in another to ask the sacrifice of time and labour in doing her chemical work. Chemistry is a wide field, and many zealous lives are now being spent in the prosecution of it, without at all entering upon the domain of practical agriculture."

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